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(54) **2'-CYANO SUBSTITUTED NUCLEOSIDE DERIVATIVES AND METHODS OF USE THEREOF FOR THE TREATMENT OF VIRAL DISEASES**

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CPC **C07D 487/04** (2013.01); **A61K 31/706** (2013.01); **A61K 31/7056** (2013.01); **A61K 38/212** (2013.01); **A61K 45/06** (2013.01); **A61K 47/48215** (2013.01); **C07F 9/65616** (2013.01); **C07F 9/65744** (2013.01)

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CPC **C07H 19/12**; **C07H 19/23**; **A61K 31/7052**

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See application file for complete search history.

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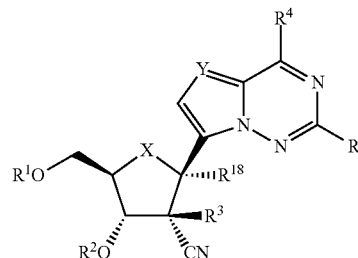
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ABSTRACT

Compounds of Formula (I) are disclosed, wherein R¹, R², R³, R⁴, R⁵, and R¹⁸ are defined herein. The compounds encompassed by Formula (I) include compounds which are HCV NS5B inhibitors and other compounds which can be metabolized in vivo to HCV NS5B inhibitors. The compounds and their pharmaceutically acceptable salts are useful for the prophylaxis or treatment of infection by HCV and the prophylaxis, treatment, or delay in the onset of disease caused by HCV. The compounds and their salts can be employed as ingredients in pharmaceutical compositions, optionally in combination with other antivirals, immunomodulators, antibiotics or vaccines.

(I)



17 Claims, No Drawings

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1

2'-CYANO SUBSTITUTED NUCLEOSIDE DERIVATIVES AND METHODS OF USE THEREOF FOR THE TREATMENT OF VIRAL DISEASES

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a §371 National Stage Application of PCT/CN2013/085060, international filing date of Oct. 11, 2013, which claims the benefit of U.S. Provisional Application No. 61/715,024, filed Oct. 17, 2012, the contents of which are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates to 2'-Cyano Substituted Nucleoside Derivatives, compositions comprising at least one 2'-Cyano Substituted Nucleoside Derivative, and methods of using the 2'-Cyano Substituted Nucleoside Derivatives for treating or preventing HCV infection in a patient.

REFERENCE TO SEQUENCE LISTING SUBMITTED ELECTRONICALLY

The sequence listing of the present application is submitted electronically via EFS-Web as an ASCII formatted sequence listing with a file name "23338USPCT-SEQLIST-17APR2015.TXT", creation date of Apr. 16, 2015, and a size of 4.00 KB. This sequence listing submitted via EFS-Web is part of the specification and is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

Hepatitis C virus (HCV) infection is a major health problem that leads to chronic liver disease, such as cirrhosis and hepatocellular carcinoma, in a substantial number of infected individuals, estimated to be 2-15% of the world's population. There are over 3 million chronically infected people in the United States alone, according to the U.S. Center for Disease Control. About 150 million individuals are chronically infected worldwide, with at least 3 to 4 million people being infected each year. Hepatitis C Fact Sheet, World Health Organization, July 2012. Once infected, about 20% of people clear the virus, but the rest harbor HCV the rest of their lives. Ten to twenty percent of chronically infected individuals eventually develop liver-destroying cirrhosis or cancer. HCV is transmitted parenterally by contaminated blood and blood products, contaminated needles, or sexually and vertically from infected mothers or carrier mothers to their off-spring.

Different approaches to HCV therapy have been taken, which include the inhibition of viral serine proteinase (NS3 protease), helicase, and RNA-dependent RNA polymerase (NS5B), and the development of a vaccine. Current and investigational treatments for HCV infection are reviewed in Poordad et al., Treating hepatitis C: current standard of care and emerging direct-acting antiviral agents. *Journal of Viral Hepatitis* 19: 449-464 (2012); Asselah et al., Protease and polymerase inhibitors for the treatment of hepatitis C. *Liver International* 29(s1): 57-67 (2009); G. J. Dore. The changing therapeutic landscape for hepatitis C. *Med. J. Australia* 196: 629-632 (2012); and Balsano, *Mini Rev. Med. Chem.* 8(4): 307-318, 2008. Despite the availability of therapeutic treatment options, chronic HCV infection remains a major health-care concern. Moreover, there is no established vaccine for

2

HCV. Consequently, there is a need for improved therapeutic agents that effectively combat chronic HCV infection.

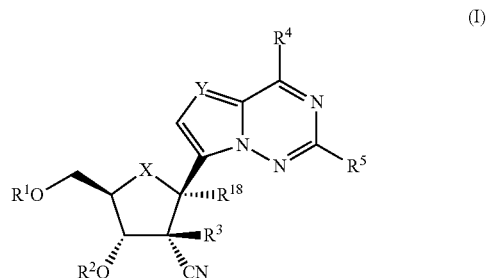
The HCV virion is an enveloped positive-strand RNA virus with a single oligoribonucleotide genomic sequence of about 9400 bases which encodes a polyprotein of about 3,000 amino acids. The protein products of the HCV gene consist of the structural proteins C, E1, and E2, and the non-structural proteins NS2, NS3, NS4A, NS4B, NS5A and NS5B. The nonstructural (NS) proteins are believed to provide the catalytic machinery for viral replication.

The NS3 protease releases NS5B, the RNA-dependent RNA polymerase from the polyprotein chain. HCV NS5B polymerase is required for the synthesis of a negative-strand RNA intermediate from a positive-strand genomic viral RNA that serves as a template in the replication cycle of HCV. NS5B polymerase is an essential component in the HCV replication complex. See K. Ishi, et al., "Expression of Hepatitis C Virus NS5B Protein: Characterization of Its RNA Polymerase Activity and RNA Binding," *Hepatology*, 29:1227-1235 (1999) and V. Lohmann, et al., "Biochemical and Kinetic Analyses of NS5B RNA-Dependent RNA Polymerase of the Hepatitis C Virus," *Virology*, 249:108-118 (1998) Inhibition of HCV NS5B polymerase prevents formation of the double-stranded HCV RNA and therefore constitutes an attractive approach to the development of HCV-specific antiviral therapies.

The development of inhibitors of HCV NS5B polymerase with potential for the treatment of HCV infection has been reviewed in Poordad et al. (2012), supra; Asselah et al. (2009), supra; and Chatel-Chaix et al. Direct-acting and host-targeting HCV inhibitors: current and future directions. *Current Opinion in Virology*, 2:588-598 (2012). The activity of purine ribonucleosides against HCV polymerase was reported by A. E. Eldrup et al., "Structure-Activity Relationship of Purine Ribonucleosides for Inhibition of HCV RNA-Dependent RNA Polymerase," *J. Med. Chem.*, 47:2283-2295 (2004). Nucleoside analogs said to be useful in the treatment of hepatitis C are disclosed in WO 2011/035231, WO 2005/003147, WO 2010/0081628, U.S. Pat. No. 7,879,815, WO 2010/075517, WO 2010/002877, and WO 2009/132123.

SUMMARY OF THE INVENTION

In one aspect, the present invention provides Compounds of Formula (I):



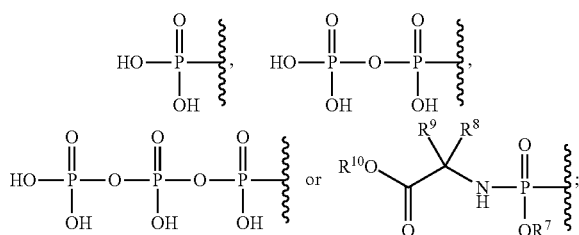
or a pharmaceutically acceptable salt thereof, wherein:

X is O, N, S or CH₂;

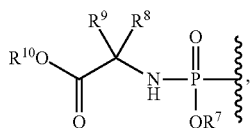
Y is N or —C(R⁶)—;

R¹ is H,

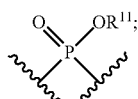
3



R^2 is H, $-\text{C}(\text{O})-(\text{C}_1\text{-C}_6 \text{ alkyl})$ or



or R^1 and R^2 join to form a group having the formula:



R^3 is $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ alkynyl or $\text{C}_3\text{-C}_7$ cycloalkyl;

R^4 and R^5 are each independently selected from H, $-\text{OR}^{12}$, $-\text{NHC}(\text{O})\text{OR}^{12}$, $-\text{NHC}(\text{O})\text{N}(\text{R}^{12})_2$, $-\text{N}(\text{R}^{12})_2$ and $-\text{NHC}(\text{O})\text{R}^{12}$;

R^6 is H, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, halo, $-\text{OR}^{12}$, $-\text{SR}^{12}$, $-\text{N}(\text{R}^{12})_2$, $\text{C}_3\text{-C}_7$ cycloalkyl, $\text{C}_6\text{-C}_{10}$ aryl, 5- or 6-membered monocyclic heteroaryl or 9- or 10-membered bicyclic heteroaryl;

R^7 is H, $\text{C}_6\text{-C}_{10}$ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, or $-(\text{C}_1\text{-C}_3 \text{ alkylene})-\text{C}(\text{O})\text{O}-(\text{C}_1\text{-C}_6 \text{ alkyl})$, wherein said $\text{C}_6\text{-C}_{10}$ aryl group, said 5- or 6-membered monocyclic heteroaryl group and said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with R^{13} ;

R^8 is H, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_3\text{-C}_7$ cycloalkyl, phenyl or benzyl, wherein said $\text{C}_1\text{-C}_6$ alkyl can be optionally substituted with a group selected from halo, $-\text{OR}^{12}$, $-\text{SR}^{12}$, guanidino, $-\text{N}(\text{R}^{12})_2$, $-\text{C}(\text{O})\text{OR}^{12}$, $-\text{C}(\text{O})\text{N}(\text{R}^{12})_2$, $-\text{NHC}(\text{O})\text{R}^{12}$, 5- or 6-membered monocyclic heteroaryl and 9- or 10-membered bicyclic heteroaryl, and wherein said phenyl group and said benzyl group can be optionally substituted with up to 2 groups, each independently selected from $\text{C}_1\text{-C}_6$ alkyl, halo and $-\text{OR}^{12}$;

R^9 is H, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_3\text{-C}_7$ cycloalkyl, phenyl or benzyl, wherein said $\text{C}_1\text{-C}_6$ alkyl can be optionally substituted with a group selected from halo, $-\text{OR}^{12}$, $-\text{SR}^{12}$, guanidino, $-\text{N}(\text{R}^{12})_2$, $-\text{C}(\text{O})\text{OR}^{12}$, $-\text{C}(\text{O})\text{N}(\text{R}^{12})_2$, $-\text{NHC}(\text{O})\text{R}^{12}$, 5- or 6-membered monocyclic heteroaryl and 9- or 10-membered bicyclic heteroaryl, and wherein said phenyl group and said benzyl group can be optionally substituted with up to 2 groups, each independently selected from $\text{C}_1\text{-C}_6$ alkyl, halo and $-\text{OR}^{12}$;

R^{10} is H, $\text{C}_1\text{-C}_{20}$ alkyl, $\text{C}_2\text{-C}_{20}$ alkenyl, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_3\text{-C}_7 \text{ cycloalkyl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_6\text{-C}_{10} \text{ aryl})$ or $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m\text{-adamantyl}$, wherein said $\text{C}_1\text{-C}_{20}$ alkyl group, said $\text{C}_2\text{-C}_{20}$ alkenyl group, said $\text{C}_6\text{-C}_{10}$ aryl group and said adamantyl group can be optionally sub-

4

stituted with up to three groups, each independently selected from halo, $-\text{OR}^{12}$, $-\text{C}(\text{O})\text{OR}^{12}$, CN, NO_2 , $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $\text{C}_3\text{-C}_7$ cycloalkyl, $\text{C}_6\text{-C}_{10}$ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, $-\text{N}(\text{R}^{12})_2$, $-\text{C}(\text{O})\text{N}(\text{R}^{12})_2$, $-\text{SR}^{12}$, $-\text{S}(\text{O})\text{R}^{12}$, $-\text{S}(\text{O})_2\text{R}^{12}$, $-\text{S}(\text{O})_2\text{N}(\text{R}^{12})_2$, $-\text{NHC}(\text{O})\text{R}^{12}$, $-\text{NHC}(\text{O})\text{OR}^{12}$ and $-\text{NHC}(\text{O})\text{N}(\text{R}^{12})_2$;

R^{11} is H, $\text{C}_1\text{-C}_{20}$ alkyl, $\text{C}_2\text{-C}_{20}$ alkenyl, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_3\text{-C}_7 \text{ cycloalkyl})$, $\text{C}_3\text{-C}_7$ cycloalkyl, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-\text{C}_6\text{-C}_{10}$ aryl or $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m\text{-adamantyl}$, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, wherein said $\text{C}_1\text{-C}_{20}$ alkyl group, said $\text{C}_2\text{-C}_{20}$ alkenyl group, said $\text{C}_6\text{-C}_{10}$ aryl group, said adamantyl group, said 5- or 6-membered monocyclic heteroaryl group and said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with up to five groups, each independently selected from $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ alkynyl, $\text{C}_3\text{-C}_7$ cycloalkyl, $\text{C}_6\text{-C}_{10}$ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, halo, $-\text{OR}^{12}$, $-\text{SR}^{12}$, $-\text{S}(\text{O})\text{R}^{12}$, $-\text{S}(\text{O})_2\text{R}^{12}$, $-\text{S}(\text{O})_2\text{N}(\text{R}^{12})_2$, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $-(\text{C}_1\text{-C}_6 \text{ haloalkyl})$, $-\text{CN}$, $-\text{NO}_2$, $-\text{N}(\text{R}^{12})_2$, $-\text{C}(\text{O})\text{OR}^{12}$, $-\text{C}(\text{O})\text{N}(\text{R}^{12})_2$ and $-\text{NHC}(\text{O})\text{R}^{12}$, $-\text{NHC}(\text{O})\text{OR}^{12}$ and $-\text{NHC}(\text{O})\text{N}(\text{R}^{12})_2$;

each occurrence of R^{12} is independently H, $\text{C}_1\text{-C}_{10}$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_3\text{-C}_7 \text{ cycloalkyl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_6\text{-C}_{10} \text{ aryl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(4 \text{ to } 7\text{-membered heterocycloalkyl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(5\text{- or } 6\text{-membered monocyclic heteroaryl})$ or $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(9\text{- or } 10\text{-membered bicyclic heteroaryl})$, wherein said $\text{C}_3\text{-C}_7$ cycloalkyl group, said $\text{C}_6\text{-C}_{10}$ aryl group, said 4 to 7-membered heterocycloalkyl group, said 5- or 6-membered monocyclic heteroaryl group or said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with R^{16} ;

R^{13} represents from one to five substituent groups, each independently selected from $\text{C}_1\text{-C}_6$ alkyl, halo, $-\text{OR}^{12}$, $-\text{SR}^{12}$, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $-(\text{C}_1\text{-C}_6 \text{ haloalkyl})$, $-\text{CN}$, $-\text{NO}_2$, $-\text{N}(\text{R}^{12})_2$, $-\text{C}(\text{O})\text{OR}^{12}$, $-\text{C}(\text{O})\text{N}(\text{R}^{12})_2$ and $-\text{NHC}(\text{O})\text{R}^{12}$, or any two R^{13} groups on adjacent ring carbon atoms can combine to form $-\text{O}-\text{R}^{14}-\text{O}-$;

R^{14} is $-\text{C}(\text{R}^{15})_2\text{-}$;

each occurrence of R^{15} is independently H or $\text{C}_1\text{-C}_6$ alkyl;

R^{16} represents from one to five substituent groups, each independently selected from $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_2\text{-C}_6$ alkenyl, $\text{C}_2\text{-C}_6$ alkynyl, halo, $-\text{OR}^{17}$, $-\text{SR}^{17}$, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $-(\text{C}_1\text{-C}_6 \text{ haloalkyl})$, $-\text{CN}$, $-\text{NO}_2$, $-\text{N}(\text{R}^{17})_2$, $-\text{C}(\text{O})\text{OR}^{17}$, $-\text{C}(\text{O})\text{N}(\text{R}^{17})_2$ and $-\text{NHC}(\text{O})\text{R}^{17}$;

each occurrence of R^{17} is independently H, $\text{C}_1\text{-C}_6$ alkyl, $\text{C}_1\text{-C}_6$ haloalkyl, $\text{C}_1\text{-C}_6$ hydroxyalkyl, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_3\text{-C}_7 \text{ cycloalkyl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(\text{C}_6\text{-C}_{10} \text{ aryl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(4 \text{ to } 7\text{-membered heterocycloalkyl})$, $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(5\text{- or } 6\text{-membered monocyclic heteroaryl})$ or $-(\text{C}_1\text{-C}_3 \text{ alkylene})_m-(9\text{- or } 10\text{-membered bicyclic heteroaryl})$;

R^{18} is H, $\text{C}_1\text{-C}_6$ alkyl, $-(\text{C}_1\text{-C}_6 \text{ alkyl})$, $\text{C}_1\text{-C}_6$ alkynyl, $\text{C}_1\text{-C}_6$ alkenyl, or CN; and

each occurrence of m is independently 0 or 1, and

each occurrence of n is independently 1, 2, or 3.

The Compounds of Formula (I) (also referred to herein as the "2'-Cyano Substituted Nucleoside Derivatives") and pharmaceutically acceptable salts thereof can be useful, for example, for inhibiting HCV viral replication or replicon activity, and for treating or preventing HCV infection in a patient. Without being bound by any specific theory, it is

believed that the 2'-Cyano Substituted Nucleoside Derivatives inhibit HCV viral replication by inhibiting HCV NS5B.

Accordingly, the present invention provides methods for treating or preventing HCV infection in a patient, comprising administering to the patient an effective amount of at least one 2'-Cyano Substituted Nucleoside Derivative.

The details of the invention are set forth in the accompanying detailed description set forth below.

Other embodiments, aspects and features of the present invention are either further described in or will be apparent from the ensuing description, examples and appended claims.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to 2'-Cyano Substituted Nucleoside Derivatives, compositions comprising at least one 2'-Cyano Substituted Nucleoside Derivative, and methods of using the 2'-Cyano Substituted Nucleoside Derivatives for treating or preventing HCV infection in a patient.

Definitions and Abbreviations:

The terms used herein have their ordinary meaning and the meaning of such terms is independent at each occurrence thereof. That notwithstanding and except where stated otherwise, the following definitions apply throughout the specification and claims. Chemical names, common names, and chemical structures may be used interchangeably to describe the same structure. If a chemical compound is referred to using both a chemical structure and a chemical name and an ambiguity exists between the structure and the name, the structure predominates. These definitions apply regardless of whether a term is used by itself or in combination with other terms, unless otherwise indicated. Hence, the definition of "alkyl" applies to "alkyl" as well as the "alkyl" portions of "hydroxyalkyl," "haloalkyl," "—O-alkyl," etc.

As used herein, and throughout this disclosure, the following terms, unless otherwise indicated, shall be understood to have the following meanings:

A "patient" is a human or non-human mammal. In one embodiment, a patient is a human. In another embodiment, a patient is a chimpanzee.

The term "effective amount" as used herein, refers to an amount of 2'-Cyano Substituted Nucleoside Derivative and/or an additional therapeutic agent, or a composition thereof that is effective in producing the desired therapeutic, ameliorative, inhibitory or preventative effect when administered to a patient suffering from a viral infection or virus-related disorder. In the combination therapies of the present invention, an effective amount can refer to each individual agent or to the combination as a whole, wherein the amounts of all agents administered are together effective, but wherein the component agent of the combination may not be present individually in an effective amount.

The term "preventing," as used herein with respect to an HCV viral infection or HCV-virus related disorder, refers to reducing the likelihood or severity of HCV infection.

The term "alkyl," as used herein, refers to an aliphatic hydrocarbon group having one of its hydrogen atoms replaced with a bond. An alkyl group may be straight or branched and contain from about 1 to about 20 carbon atoms. In one embodiment, an alkyl group contains from about 1 to about 12 carbon atoms. In different embodiments, an alkyl group contains from 1 to 6 carbon atoms (C₁-C₆ alkyl) or from about 1 to about 4 carbon atoms (C₁-C₄ alkyl). Non-limiting examples of alkyl groups include methyl, ethyl, n-propyl, isopropyl, n-butyl, sec-butyl, isobutyl, tert-butyl, n-pentyl, neopentyl, isopentyl, n-hexyl, isohexyl and neohexyl. An alkyl group may be unsubstituted or substituted by one or

more substituents which may be the same or different, each substituent being independently selected from the group consisting of halo, alkenyl, alkynyl, aryl, cycloalkyl, cyano, hydroxy, —O-alkyl, —O-aryl, -alkylene-O-alkyl, alkylthio, —NH₂, —NH(alkyl), —N(alkyl)₂, —NH(cycloalkyl), —O—C(O)-alkyl, —O—C(O)-aryl, —O—C(O)-cycloalkyl, —C(O)OH and —C(O)O-alkyl. In one embodiment, an alkyl group is linear. In another embodiment, an alkyl group is branched. Unless otherwise indicated, an alkyl group is unsubstituted.

The term "alkenyl," as used herein, refers to an aliphatic hydrocarbon group containing at least one carbon-carbon double bond and having one of its hydrogen atoms replaced with a bond. An alkenyl group may be straight or branched and contain from about 2 to about 15 carbon atoms. In one embodiment, an alkenyl group contains from about 2 to about 12 carbon atoms. In another embodiment, an alkenyl group contains from about 2 to about 6 carbon atoms. Non-limiting examples of alkenyl groups include ethenyl, propenyl, n-butenyl, 3-methylbut-2-enyl, n-pentenyl, octenyl and decenyl. An alkenyl group may be unsubstituted or substituted by one or more substituents which may be the same or different, each substituent being independently selected from the group consisting of halo, alkenyl, alkynyl, aryl, cycloalkyl, cyano, hydroxy, —O-alkyl, —O-aryl, -alkylene-O-alkyl, alkylthio, —NH₂, —NH(alkyl), —N(alkyl)₂, —NH(cycloalkyl), —O—C(O)-alkyl, —O—C(O)-aryl, —O—C(O)-cycloalkyl, —C(O)OH and —C(O)O-alkyl. The term "C₂-C₆ alkenyl" refers to an alkenyl group having from 2 to 6 carbon atoms. Unless otherwise indicated, an alkenyl group is unsubstituted.

The term "alkynyl," as used herein, refers to an aliphatic hydrocarbon group containing at least one carbon-carbon triple bond and having one of its hydrogen atoms replaced with a bond. An alkynyl group may be straight or branched and contain from about 2 to about 15 carbon atoms. In one embodiment, an alkynyl group contains from about 2 to about 12 carbon atoms. In another embodiment, an alkynyl group contains from about 2 to about 6 carbon atoms. Non-limiting examples of alkynyl groups include ethynyl, propynyl, 2-butyne and 3-methylbutynyl. An alkynyl group may be unsubstituted or substituted by one or more substituents which may be the same or different, each substituent being independently selected from the group consisting of halo, alkenyl, alkynyl, aryl, cycloalkyl, cyano, hydroxy, —O-alkyl, —O-aryl, -alkylene-O-alkyl, alkylthio, —NH₂, —NH(alkyl), —N(alkyl)₂, —NH(cycloalkyl), —O—C(O)-alkyl, —O—C(O)-aryl, —O—C(O)-cycloalkyl, —C(O)OH and —C(O)O-alkyl. The term "C₂-C₆ alkynyl" refers to an alkynyl group having from 2 to 6 carbon atoms. Unless otherwise indicated, an alkynyl group is unsubstituted.

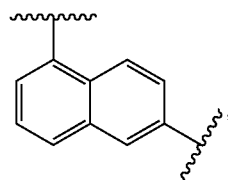
The term "alkylene," as used herein, refers to an alkyl group, as defined above, wherein one of the alkyl group's hydrogen atoms has been replaced with a bond. Non-limiting examples of alkylene groups include —CH₂—, —CH₂CH₂—, —CH₂CH₂CH₂—, —CH₂CH₂CH₂CH₂—, —CH(CH₃)CH₂CH₂—, —CH(CH₃)— and —CH₂CH(CH₃)CH₂—. In one embodiment, an alkylene group has from 1 to about 6 carbon atoms. In another embodiment, an alkylene group is branched. In another embodiment, an alkylene group is linear. In one embodiment, an alkylene group is —CH₂—. The term "C₁-C₆ alkylene" refers to an alkylene group having from 1 to 6 carbon atoms.

The term "aryl," as used herein, refers to an aromatic monocyclic or polycyclic ring system comprising from about 6 to about 14 carbon atoms. In one embodiment, an aryl group contains from about 6 to about 10 carbon atoms. An

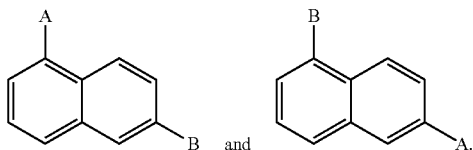
7

aryl group can be optionally substituted with one or more “ring system substituents” which may be the same or different, and are as defined herein below. In one embodiment, an aryl group can be optionally fused to a cycloalkyl or cycloalkanoyl group. Non-limiting examples of aryl groups include phenyl and naphthyl. In one embodiment, an aryl group is phenyl. Unless otherwise indicated, an aryl group is unsubstituted.

The term “arylene,” as used herein, refers to a bivalent group derived from an aryl group, as defined above, by removal of a hydrogen atom from a ring carbon of an aryl group. An arylene group can be derived from a monocyclic or multicyclic ring system comprising from about 6 to about 14 carbon atoms. In one embodiment, an arylene group contains from about 6 to about 10 carbon atoms. In another embodiment, an arylene group is a naphthylene group. In another embodiment, an arylene group is a phenylene group. An arylene group can be optionally substituted with one or more “ring system substituents” which may be the same or different, and are as defined herein below. An arylene group is divalent and either available bond on an arylene group can connect to either group flanking the arylene group. For example, the group “A-arylene-B,” wherein the arylene group is:

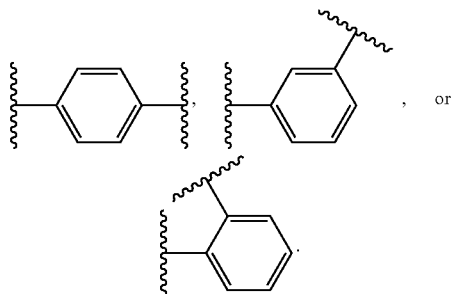


is understood to represent both:



In one embodiment, an arylene group can be optionally fused to a cycloalkyl or cycloalkanoyl group. Non-limiting examples of arylene groups include phenylene and naphthalene. In one embodiment, an arylene group is unsubstituted.

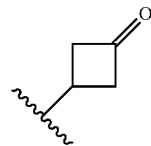
In another embodiment, an arylene group is:



Unless otherwise indicated, an arylene group is unsubstituted.

8

The term “cycloalkyl,” as used herein, refers to a non-aromatic mono- or multicyclic ring system comprising from 3 to about 10 ring carbon atoms. In one embodiment, a cycloalkyl contains from about 5 to about 10 ring carbon atoms. In another embodiment, a cycloalkyl contains from 3 to about 7 ring atoms. In another embodiment, a cycloalkyl contains from about 5 to about 6 ring atoms. The term “cycloalkyl” also encompasses a cycloalkyl group, as defined above, which is fused to an aryl (e.g., benzene) or heteroaryl ring. Non-limiting examples of monocyclic cycloalkyls include cyclopropyl, cyclobutyl, cyclopentyl, cyclohexyl, cycloheptyl and cyclooctyl. Non-limiting examples of multicyclic cycloalkyls include 1-decalinyl, norbornyl and adamantyl. A cycloalkyl group can be optionally substituted with one or more “ring system substituents” which may be the same or different, and are as defined herein below. In one embodiment, a cycloalkyl group is unsubstituted. The term “3 to 6-membered cycloalkyl” refers to a cycloalkyl group having from 3 to 6 ring carbon atoms. Unless otherwise indicated, a cycloalkyl group is unsubstituted. A ring carbon atom of a cycloalkyl group may be functionalized as a carbonyl group. An illustrative example of such a cycloalkyl group (also referred to herein as a “cycloalkanoyl” group) includes, but is not limited to, cyclobutanoyl:



The term “halo,” as used herein, means —F, —Cl, —Br or —I.

The term “haloalkyl,” as used herein, refers to an alkyl group as defined above, wherein one or more of the alkyl group’s hydrogen atoms have been replaced with a halogen. In one embodiment, a haloalkyl group has from 1 to 6 carbon atoms. In another embodiment, a haloalkyl group is substituted with from 1 to 3 F atoms. Non-limiting examples of haloalkyl groups include —CH₂F, —CHF₂, —CF₃, —CH₂Cl and —CCl₃. The term “C₁-C₆ haloalkyl” refers to a haloalkyl group having from 1 to 6 carbon atoms.

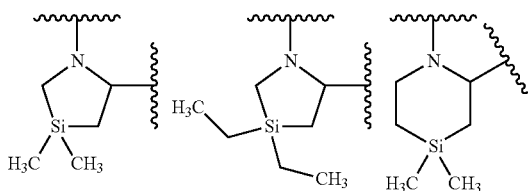
The term “hydroxyalkyl,” as used herein, refers to an alkyl group as defined above, wherein one or more of the alkyl group’s hydrogen atoms have been replaced with an —OH group. In one embodiment, a hydroxyalkyl group has from 1 to 6 carbon atoms. Non-limiting examples of hydroxyalkyl groups include —CH₂OH, —CH₂CH₂OH, —CH₂CH₂CH₂OH and —CH₂CH(OH)CH₃. The term “C₁-C₆ hydroxyalkyl” refers to a hydroxyalkyl group having from 1 to 6 carbon atoms.

The term “heteroaryl,” as used herein, refers to an aromatic monocyclic or multicyclic ring system comprising about 5 to about 14 ring atoms, wherein from 1 to 4 of the ring atoms is independently O, N or S and the remaining ring atoms are carbon atoms. In one embodiment, a heteroaryl group has 5 to 10 ring atoms. In another embodiment, a heteroaryl group is monocyclic and has 5 or 6 ring atoms. In another embodiment, a heteroaryl group is bicyclic. A heteroaryl group can be optionally substituted by one or more “ring system substituents” which may be the same or different, and are as defined herein below. A heteroaryl group is joined via a ring carbon atom, and any nitrogen atom of a heteroaryl can be optionally oxidized to the corresponding N-oxide. The term “heteroaryl” also encompasses a heteroaryl group, as defined

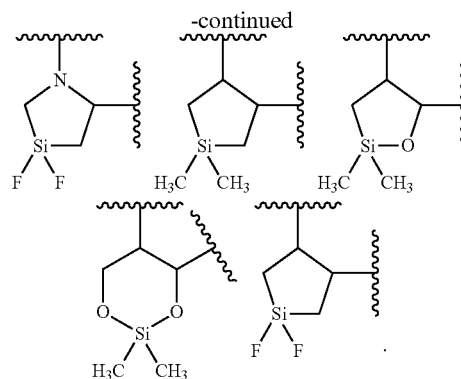
9

above, which is fused to a benzene ring. Non-limiting examples of heteroaryls include pyridyl, pyrazinyl, furanyl, thienyl, pyrimidinyl, pyridone (including N-substituted pyridones), isoxazolyl, isothiazolyl, oxazolyl, oxadiazolyl, thiazolyl, pyrazolyl, furazanyl, pyrrolyl, triazolyl, 1,2,4-thiadiazolyl, pyrazinyl, pyridazinyl, quinoxalyl, phthalazinyl, oxindolyl, imidazo[1,2-a]pyridinyl, imidazo[2,1-b]thiazolyl, benzofurazanyl, indolyl, azaindolyl, benzimidazolyl, benzothienyl, quinolinyl, imidazolyl, benzimidazolyl, thienopyridyl, quinazolinyl, thienopyrimidyl, pyrrolopyridyl, imidazopyridyl, isoquinolinyl, benzoazaindolyl, 1,2,4-triazinyl, benzothiazolyl and the like, and all isomeric forms thereof. The term "heteroaryl" also refers to partially saturated heteroaryl moieties such as, for example, tetrahydroisoquinolyl, tetrahydroquinolyl and the like. In one embodiment, a heteroaryl group is a 5-membered heteroaryl. In another embodiment, a heteroaryl group is a 6-membered heteroaryl. In another embodiment, a heteroaryl group comprises a 5- to 6-membered heteroaryl group fused to a benzene ring. Unless otherwise indicated, a heteroaryl group is unsubstituted.

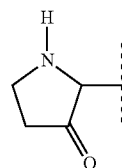
The term "heterocycloalkyl," as used herein, refers to a non-aromatic saturated monocyclic or multicyclic ring system comprising 3 to about 11 ring atoms, wherein from 1 to 4 of the ring atoms are independently O, S, N or Si, and the remainder of the ring atoms are carbon atoms. A heterocycloalkyl group can be joined via a ring carbon, ring silicon atom or ring nitrogen atom. In one embodiment, a heterocycloalkyl group is monocyclic and has from 3 to about 7 ring atoms. In another embodiment, a heterocycloalkyl group is monocyclic has from about 4 to about 7 ring atoms. In another embodiment, a heterocycloalkyl group is bicyclic and has from about 7 to about 11 ring atoms. In still another embodiment, a heterocycloalkyl group is monocyclic and has 5 or 6 ring atoms. In one embodiment, a heterocycloalkyl group is monocyclic. In another embodiment, a heterocycloalkyl group is bicyclic. There are no adjacent oxygen and/or sulfur atoms present in the ring system. Any —NH group in a heterocycloalkyl ring may exist protected such as, for example, as an —N(BOC), —N(Cbz), —N(Tos) group and the like; such protected heterocycloalkyl groups are considered part of this invention. The term "heterocycloalkyl" also encompasses a heterocycloalkyl group, as defined above, which is fused to an aryl (e.g., benzene) or heteroaryl ring. A heterocycloalkyl group can be optionally substituted by one or more "ring system substituents" which may be the same or different, and are as defined herein below. The nitrogen or sulfur atom of the heterocycloalkyl can be optionally oxidized to the corresponding N-oxide, S-oxide or S,S-dioxide. Non-limiting examples of monocyclic heterocycloalkyl rings include oxetanyl, piperidyl, pyrrolidinyl, piperazinyl, morpholinyl, thiomorpholinyl, thiazolidinyl, 1,4-dioxanyl, tetrahydrofuranyl, tetrahydrothiophenyl, delta-lactam, delta-lactone, silacyclopentane, silapyrrolidine and the like, and all isomers thereof. Non-limiting illustrative examples of a silyl-containing heterocycloalkyl group include:



10



A ring carbon atom of a heterocycloalkyl group may be functionalized as a carbonyl group. An illustrative example of such a heterocycloalkyl group is:

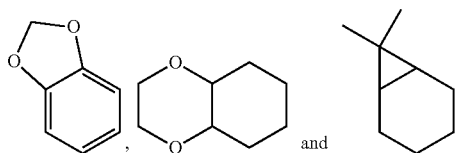


In one embodiment, a heterocycloalkyl group is a 5-membered monocyclic heterocycloalkyl. In another embodiment, a heterocycloalkyl group is a 6-membered monocyclic heterocycloalkyl. The term "3 to 6-membered monocyclic cycloalkyl" refers to a monocyclic heterocycloalkyl group having from 3 to 6 ring atoms. The term "4 to 6-membered monocyclic cycloalkyl" refers to a monocyclic heterocycloalkyl group having from 4 to 6 ring atoms. The term "7 to 11-membered bicyclic heterocycloalkyl" refers to a bicyclic heterocycloalkyl group having from 7 to 11 ring atoms. Unless otherwise indicated, an heterocycloalkyl group is unsubstituted.

The term "ring system substituent," as used herein, refers to a substituent group attached to an aromatic or non-aromatic ring system which, for example, replaces an available hydrogen on the ring system. Ring system substituents may be the same or different, and are each independently selected. Examples of ring system substituents include alkyl, alkenyl, alkynyl, aryl, heteroaryl, -alkylene-aryl, -arylene-alkyl, -alkylene-heteroaryl, -alkenylene-heteroaryl, -alkynylene-heteroaryl, —OH, hydroxyalkyl, haloalkyl, —O-alkyl, —O-haloalkyl, -alkylene-O-alkyl, —O-aryl, —O-alkylene-aryl, acyl, —C(O)-aryl, halo, —NO₂, —CN, —SF₅, —C(O)OH, —C(O)O-alkyl, —C(O)O-aryl, —C(O)O-alkylene-aryl, —S(O)-alkyl, —S(O)₂-alkyl, —S(O)-aryl, —S(O)₂-aryl, —S(O)-heteroaryl, —S(O)₂-heteroaryl, —S-alkyl, —S-aryl, —S-heteroaryl, —S-alkylene-aryl, —S-alkylene-heteroaryl, —S(O)₂-alkylene-aryl, —S(O)₂-alkylene-heteroaryl, —Si(alkyl)₂, —Si(aryl)₂, —Si(heteroaryl)₂, —Si(alkyl)(aryl), —Si(alkyl)(cycloalkyl), —Si(alkyl)(heteroaryl), cycloalkyl, heterocycloalkyl, —O—C(O)-alkyl, —O—C(O)-aryl, —O—C(O)-cycloalkyl, —C(=N—CN)—NH₂, —C(=NH)—NH₂, —C(=NH)—NH(alkyl), —N(Y₁)(Y₂), -alkylene-N(Y₁)(Y₂), —C(O)N(Y₁)(Y₂) and —S(O)₂N(Y₁)(Y₂), wherein Y₁ and Y₂ can be the same or different and are independently selected from the group consisting of hydrogen, alkyl, aryl, cycloalkyl, and -alkylene-aryl. "Ring system substituent" may also mean a single moiety which simulta-

11

neously replaces two available hydrogens on two adjacent carbon atoms (one H on each carbon) on a ring system. Examples of such moiety are methylenedioxy, ethylenedioxy, $-\text{C}(\text{CH}_3)_2-$ and the like which form moieties such as, for example:



The term “substituted” means that one or more hydrogens on the designated atom is replaced with a selection from the indicated group, provided that the designated atom’s normal valency under the existing circumstances is not exceeded, and that the substitution results in a stable compound. Combinations of substituents and/or variables are permissible only if such combinations result in stable compounds. By “stable compound” or “stable structure” is meant a compound that is sufficiently robust to survive isolation to a useful degree of purity from a reaction mixture, and formulation into an efficacious therapeutic agent.

The term “in substantially purified form,” as used herein, refers to the physical state of a compound after the compound is isolated from a synthetic process (e.g., from a reaction mixture), a natural source, or a combination thereof. The term “in substantially purified form,” also refers to the physical state of a compound after the compound is obtained from a purification process or processes described herein or well-known to the skilled artisan (e.g., chromatography, recrystallization and the like), in sufficient purity to be characterizable by standard analytical techniques described herein or well-known to the skilled artisan.

It should also be noted that any carbon as well as heteroatom with unsatisfied valences in the text, schemes, examples and tables herein is assumed to have the sufficient number of hydrogen atom(s) to satisfy the valences.

When a functional group in a compound is termed “protected”, this means that the group is in modified form to preclude undesired side reactions at the protected site when the compound is subjected to a reaction. Suitable protecting groups will be recognized by those with ordinary skill in the art as well as by reference to standard textbooks such as, for example, T. W. Greene et al, *Protective Groups in Organic Synthesis* (1991), Wiley, New York.

When any substituent or variable (e.g., alkyl, R^6 , R^a , etc.) occurs more than one time in any constituent or in Formula (I), its definition on each occurrence is independent of its definition at every other occurrence, unless otherwise indicated.

As used herein, the term “composition” is intended to encompass a product comprising the specified ingredients in the specified amounts, as well as any product which results, directly or indirectly, from combination of the specified ingredients in the specified amounts.

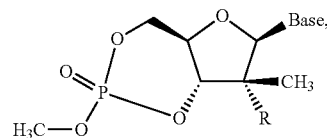
Prodrugs and solvates of the compounds of the invention are also contemplated herein. A discussion of prodrugs is provided in T. Higuchi and V. Stella, *Pro-drugs as Novel Delivery Systems* (1987) 14 of the A.C.S. Symposium Series, and in *Bioreversible Carriers in Drug Design*, (1987) Edward B. Roche, ed., American Pharmaceutical Association and Pergamon Press. The term “prodrug” means a compound (e.g., a drug precursor) that is transformed in vivo to provide

12

a 2'-Cyano Substituted Nucleoside Derivative or a pharmaceutically acceptable salt of the compound. The transformation may occur by various mechanisms (e.g., by metabolic or chemical processes), such as, for example, through hydrolysis in blood.

For example, if a 2'-Cyano Substituted Nucleoside Derivative or a pharmaceutically acceptable salt, hydrate or solvate of the compound contains a carboxylic acid functional group, a prodrug can comprise an ester formed by the replacement of the hydrogen atom of the acid group with a group such as, for example, (C_1-C_8) alkyl, $(\text{C}_2-\text{C}_{12})$ alkanoyloxymethyl, 1-(alkanoyloxy)ethyl having from 4 to 9 carbon atoms, 1-methyl-1-(alkanoyloxy)-ethyl having from 5 to 10 carbon atoms, alkoxycarbonyloxymethyl having from 3 to 6 carbon atoms, 1-(alkoxycarbonyloxy)ethyl having from 4 to 7 carbon atoms, 1-methyl-1-(alkoxycarbonyloxy)ethyl having from 5 to 8 carbon atoms, N-(alkoxycarbonyl)aminomethyl having from 3 to 9 carbon atoms, 1-(N-(alkoxycarbonyl)amino)ethyl having from 4 to 10 carbon atoms, 3-phthalidyl, 4-crotonolactonyl, gamma-butyrolacton-4-yl, di-N,N- (C_1-C_2) alkylamino (C_2-C_3) alkyl (such as β -dimethylaminoethyl), carbamoyl- (C_1-C_2) alkyl, N,N-di (C_1-C_2) alkylcarbamoyl- (C_1-C_2) alkyl and piperidino-, pyrrolidino- or morpholino (C_2-C_3) alkyl, and the like.

Similarly, if a 2'-Cyano Substituted Nucleoside Derivative contains an alcohol functional group, a prodrug can be formed by the replacement of one or more of the hydrogen atoms of the alcohol groups with a group such as, for example, (C_1-C_6) alkanoyloxymethyl, 1- (C_1-C_6) alkanoyloxyethyl, 1-methyl-1- (C_1-C_6) alkanoyloxyethyl, (C_1-C_6) alkoxycarbonyloxymethyl, N- (C_1-C_6) alkoxycarbonylaminomethyl, succinoyl, (C_1-C_6) alkanoyl, α -amino (C_1-C_4) alkyl, α -amino (C_1-C_4) alkylene-aryl, arylacyl and α -aminoacyl, or α -aminoacyl- α -aminoacyl, where each α -aminoacyl group is independently selected from the naturally occurring L-amino acids, or glycosyl (the radical resulting from the removal of a hydroxyl group of the hemiacetal form of a carbohydrate). Other non-limiting examples of alcohol-derived prodrugs include $-\text{P}(\text{O})(\text{OH})_2$; $-\text{P}(\text{O})(-\text{O}-\text{C}_1-\text{C}_6\text{alkyl})_2$; $-\text{P}(\text{O})(-\text{NH}-(\alpha\text{-aminoacyl group}))(-\text{O-aryl})$; $-\text{P}(\text{O})(-\text{O}-(\text{C}_1-\text{C}_6\text{alkylene})-\text{S-acyl})(-\text{NH-arylalkyl})$; any cyclic phosphate ester that forms a bridge between two ribose hydroxyl groups, such as:



wherein the cyclic phosphate ester forms a bridge between the 3'-OH group and 5'-OH groups; and those described in U.S. Pat. No. 7,879,815; International Publication Nos. WO2005/003047, WO2008/082602, WO2010/0081628, WO2010/075517 and WO2010/075549; Mehellou, *Chem. Med. Chem.*, 5:1841-1842 (2005); Bobeck et al., *Antiviral Therapy* 15:935-950 (2010); Furman et al., *Future Medicinal Chemistry*, 1:1429-1452 (2009); and Erion, *Microsomes and Drug Oxidations, Proceedings of the International Symposium*, 17th, Saratoga Springs, N.Y., United States, Jul. 6-10, 2008, 7-12 (2008).

13

If a 2'-Cyano Substituted Nucleoside Derivative incorporates an amine functional group, a prodrug can be formed by the replacement of a hydrogen atom in the amine group with a group such as, for example, R-carbonyl-, RO-carbonyl-, NRR'-carbonyl—wherein R and R' are each independently (C₁-C₁₀)alkyl, (C₃-C₇) cycloalkyl, benzyl, a natural α -aminoacyl, —C(OH)C(O)OY¹ wherein Y¹ is H, (C₁-C₆)alkyl or benzyl, —C(OY²)Y³ wherein Y² is (C₁-C₄) alkyl and Y³ is (C₁-C₆)alkyl; carboxy (C₁-C₆)alkyl; amino(C₁-C₄)alkyl or mono-N- or di-N,N—(C₁-C₆)alkylaminoalkyl; —C(Y⁴)Y⁵ wherein Y⁴ is H or methyl and Y⁵ is mono-N- or di-N,N—(C₁-C₆)alkylamino morpholino; piperidin-1-yl or pyrrolidin-1-yl, and the like.

Pharmaceutically acceptable esters of the present compounds include the following groups: (1) carboxylic acid esters obtained by esterification of the hydroxy group of a hydroxyl compound, in which the non-carbonyl moiety of the carboxylic acid portion of the ester grouping is selected from straight or branched chain alkyl (e.g., methyl, ethyl, n-propyl, isopropyl, t-butyl, sec-butyl or n-butyl), alkoxyalkyl (e.g., methoxymethyl), aralkyl (e.g., benzyl), aryloxyalkyl (for example, phenoxymethyl), aryl (e.g., phenyl optionally substituted with, for example, halogen, C₁₋₄alkyl, —O—(C₁₋₄)alkyl) or amino); (2) sulfonate esters, such as alkyl- or aralkylsulfonyl (for example, methanesulfonyl); (3) amino acid esters (e.g., L-valyl or L-isoleucyl); (4) phosphonate esters and (5) mono-, di- or triphosphate esters. The phosphate esters may be further esterified by, for example, a C₁₋₂₀ alcohol or reactive derivative thereof, or by a 2,3-di (C₆₋₂₄) acyl glycerol.

One or more compounds of the invention may exist in unsolvated as well as solvated forms with pharmaceutically acceptable solvents such as water, ethanol, and the like, and it is intended that the invention embrace both solvated and unsolvated forms. "Solvate" means a physical association of a compound of this invention with one or more solvent molecules. This physical association involves varying degrees of ionic and covalent bonding, including hydrogen bonding. In certain instances the solvate will be capable of isolation, for example when one or more solvent molecules are incorporated in the crystal lattice of the crystalline solid. "Solvate" encompasses both solution-phase and isolatable solvates. Non-limiting examples of solvates include ethanolates, methanolates, and the like. A "hydrate" is a solvate wherein the solvent molecule is water.

One or more compounds of the invention may optionally be converted to a solvate. Preparation of solvates is generally known. Thus, for example, M. Caira et al, *J. Pharmaceutical Sci.*, 93(3), 601-611 (2004) describe the preparation of the solvates of the antifungal fluconazole in ethyl acetate as well as from water. Similar preparations of solvates, hemisolvate, hydrates and the like are described by E. C. van Tonder et al, *AAPS PharmSciTech*, 5(1), article 12 (2004); and A. L. Bingham et al, *Chem. Commun.*, 603-604 (2001). A typical, non-limiting, process involves dissolving the inventive compound in desired amounts of the desired solvent (organic or water or mixtures thereof) at a higher than room temperature, and cooling the solution at a rate sufficient to form crystals which are then isolated by standard methods. Analytical techniques such as, for example IR spectroscopy, show the presence of the solvent (or water) in the crystals as a solvate (or hydrate).

The 2'-Cyano Substituted Nucleoside Derivatives can form salts which are also within the scope of this invention. Reference to a 2'-Cyano Substituted Nucleoside Derivative herein is understood to include reference to salts thereof, unless otherwise indicated. The term "salt(s)", as employed

14

herein, denotes acidic salts formed with inorganic and/or organic acids, as well as basic salts formed with inorganic and/or organic bases. In addition, when a 2'-Cyano Substituted Nucleoside Derivative contains both a basic moiety, such as, but not limited to a pyridine or imidazole, and an acidic moiety, such as, but not limited to a carboxylic acid, zwitterions ("inner salts") may be formed and are included within the term "salt(s)" as used herein. In one embodiment, the salt is a pharmaceutically acceptable (i.e., non-toxic, physiologically acceptable) salt. In another embodiment, the salt is other than a pharmaceutically acceptable salt. Salts of the Compounds of Formula (I) may be formed, for example, by reacting a 2'-Cyano Substituted Nucleoside Derivative with an amount of acid or base, such as an equivalent amount, in a medium such as one in which the salt precipitates or in an aqueous medium followed by lyophilization.

Exemplary acid addition salts include acetates, ascorbates, benzoates, benzenesulfonates, bisulfates, borates, butyrates, citrates, camphorates, camphorsulfonates, fumarates, hydrochlorides, hydrobromides, hydroiodides, lactates, maleates, methanesulfonates, naphthalenesulfonates, nitrates, oxalates, phosphates, propionates, salicylates, succinates, sulfates, tartrates, thiocyanates, toluenesulfonates (also known as tosylates) and the like. Additionally, acids which are generally considered suitable for the formation of pharmaceutically useful salts from basic pharmaceutical compounds are discussed, for example, by P. Stahl et al, Camille G. (eds.) *Handbook of Pharmaceutical Salts. Properties, Selection and Use*. (2002) Zurich: Wiley-VCH; S. Berge et al, *Journal of Pharmaceutical Sciences* (1977) 66(1) 1-19; P. Gould, *International J. of Pharmaceutics* (1986) 33 201-217; Anderson et al, *The Practice of Medicinal Chemistry* (1996), Academic Press, New York; and in *The Orange Book* (Food & Drug Administration, Washington, D.C. on their website). These disclosures are incorporated herein by reference thereto.

Exemplary basic salts include ammonium salts, alkali metal salts such as sodium, lithium, and potassium salts, alkaline earth metal salts such as calcium and magnesium salts, salts with organic bases (for example, organic amines) such as dicyclohexylamine, t-butyl amine, choline, and salts with amino acids such as arginine, lysine and the like. Basic nitrogen-containing groups may be quaternized with agents such as lower alkyl halides (e.g., methyl, ethyl, and butyl chlorides, bromides and iodides), dialkyl sulfates (e.g., dimethyl, diethyl, and dibutyl sulfates), long chain halides (e.g., decyl, lauryl, and stearyl chlorides, bromides and iodides), aralkyl halides (e.g., benzyl and phenethyl bromides), and others.

All such acid salts and base salts are intended to be pharmaceutically acceptable salts within the scope of the invention and all acid and base salts are considered equivalent to the free forms of the corresponding compounds for purposes of the invention.

Diastereomeric mixtures can be separated into their individual diastereomers on the basis of their physical chemical differences by methods well-known to those skilled in the art, such as, for example, by chromatography and/or fractional crystallization. Enantiomers can be separated by converting the enantiomeric mixture into a diastereomeric mixture by reaction with an appropriate optically active compound (e.g., chiral auxiliary such as a chiral alcohol or Mosher's acid chloride), separating the diastereomers and converting (e.g., hydrolyzing) the individual diastereomers to the corresponding pure enantiomers. Stereochemically pure compounds may also be prepared by using chiral starting materials or by employing salt resolution techniques. Also, some of the

15

2'-Cyano Substituted Nucleoside Derivatives may be atropi-
somers (e.g., substituted biaryls) and are considered as part of
this invention. Enantiomers can also be directly separated
using chiral chromatographic techniques.

It is also possible that the 2'-Cyano Substituted Nucleoside
Derivatives may exist in different tautomeric forms, and all
such forms are embraced within the scope of the invention.
For example, all keto-enol and imine-enamine forms of the
compounds are included in the invention.

All stereoisomers (for example, geometric isomers, optical
isomers and the like) of the present compounds (including
those of the salts, solvates, hydrates, esters and prodrugs of
the compounds as well as the salts, solvates and esters of the
prodrugs), such as those which may exist due to asymmetric
carbons on various substituents, including enantiomeric
forms (which may exist even in the absence of asymmetric
carbons), rotameric forms, atropisomers, and diastereomeric
forms, are contemplated within the scope of this invention. If
a 2'-Cyano Substituted Nucleoside Derivative incorporates a
double bond or a fused ring, both the cis- and trans-forms, as
well as mixtures, are embraced within the scope of the inven-
tion.

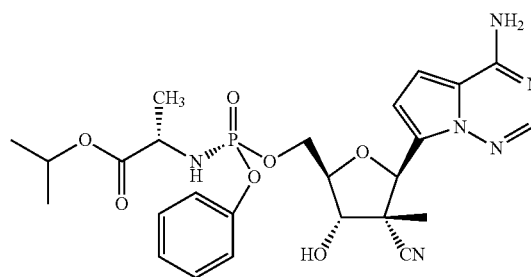
Individual stereoisomers of the compounds of the inven-
tion may, for example, be substantially free of other isomers,
or may be admixed, for example, as racemates or with all
other, or other selected, stereoisomers. The chiral centers of
the present invention can have the S or R configuration as
defined by the IUPAC 1974 Recommendations. The use of the
terms "salt", "solvate", "ester", "prodrug" and the like, is
intended to apply equally to the salt, solvate, ester and pro-
drug of enantiomers, stereoisomers, rotamers, tautomers,
positional isomers, racemates or prodrugs of the inventive
compounds.

In the Compounds of Formula (I), the atoms may exhibit
their natural isotopic abundances, or one or more of the atoms
may be artificially enriched in a particular isotope having the
same atomic number, but an atomic mass or mass number
different from the atomic mass or mass number predomi-
nantly found in nature. The present invention is meant to
include all suitable isotopic variations of the compounds of
generic Formula I. For example, different isotopic forms of
hydrogen (H) include protium (^1H) and deuterium (^2H). Pro-
tium is the predominant hydrogen isotope found in nature.
Enriching for deuterium may afford certain therapeutic
advantages, such as increasing in vivo half-life or reducing
dosage requirements, or may provide a compound useful as a
standard for characterization of biological samples. Isotopi-
cally-enriched Compounds of Formula (I) can be prepared
without undue experimentation by conventional techniques
well known to those skilled in the art or by processes analo-
gous to those described in the Schemes and Examples herein
using appropriate isotopically-enriched reagents and/or inter-
mediates. In one embodiment, a Compound of Formula (I)
has one or more of its hydrogen atoms replaced with deute-
rium.

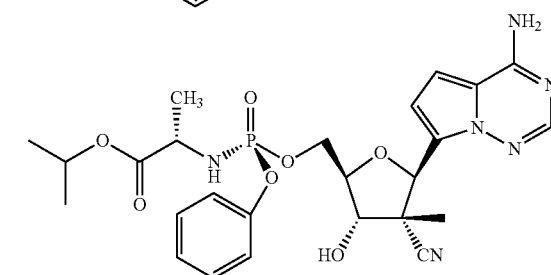
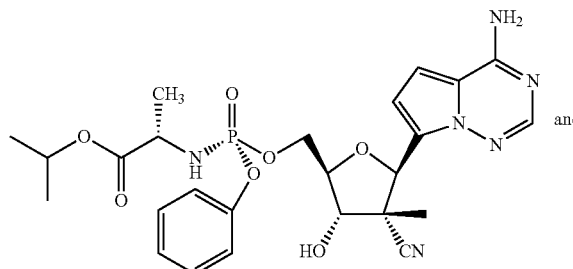
Polymorphic forms of the 2'-Cyano Substituted Nucleo-
side Derivatives, and of the salts, solvates, hydrates, esters
and prodrugs of the 2'-Cyano Substituted Nucleoside Deriva-
tives, are intended to be included in the present invention.

In some instances, the compounds of the present invention
are designated as "isomer 1" and "isomer 2." This designation
refers to stereoisomers at the chiral phosphorus atom of the
5'-prodrug moiety as illustrated below for cyclic and non-
cyclic prodrugs, wherein the structure:

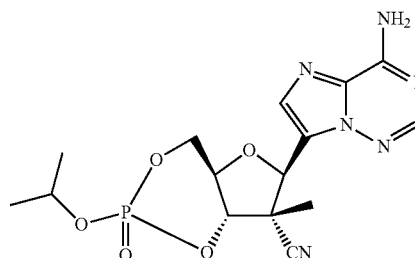
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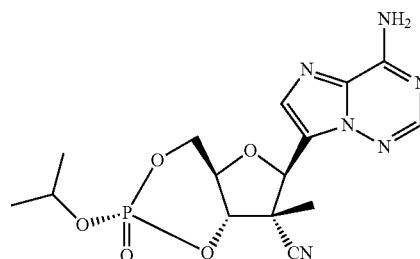
is understood to represent the following two phosphorus ste-
reoisomers:



and the structure:



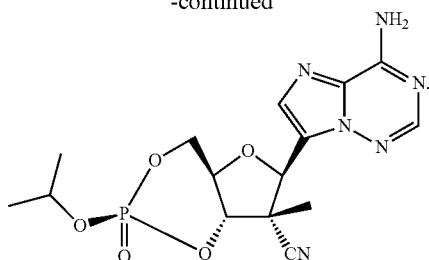
is understood to represent the following two phosphorus ste-
reoisomers:



and

17

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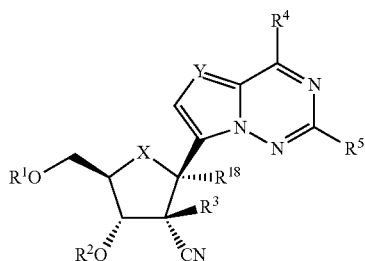


The terms “isomer 1” and “isomer 2” can be assigned to isomers of known absolute configuration or can be used to describe stereoisomers of unknown absolute configuration. Thus, the use of the terms “isomer 1” and “isomer 2” is not to be interpreted as indicating that the absolute configuration of both isomers is known.

The following abbreviations are used below and have the following meanings: Bu is butyl; BuLi is butyllithium; DCM is dichloromethane; DMF is N,N-dimethylformamide; DMSO: dimethylsulfoxide; DMAP is N,N-dimethylamino pyridine; ES is electrospray (MS), EtOAc is ethyl acetate; EtOH is ethanol; Et₂O is diethyl ether; Et₃N (alternatively NEt₃) is triethylamine; Et₃SiH is triethylsilane; h is hour(s); HPLC is high performance liquid chromatography; LCMS is liquid chromatography/mass spectrometry; LDA is lithium diisopropylamide; Me is methyl; min is minutes; MS is mass spectrum; NMR is nuclear magnetic resonance; RP-HPLC is reversed phase high-performance liquid chromatography; RT-PCR is reverse transcriptase polymerase chain reaction; sec. is second(s); TBAF is tetra n-butylammonium fluoride; TBDMSCl is tert-butyldimethylsilyl chloride; TBDMSO is t-butyldimethylsilyloxy; TFA is trifluoroacetic acid; and THF is tetrahydrofuran.

The Compounds of Formula (I):

The present invention provides 2'-Cyano Substituted Nucleoside Derivatives of Formula (I):



and pharmaceutically acceptable salts thereof, wherein R¹, R², R³, R⁴, R⁵, R¹⁸, X, and Y are as defined above for Compounds of Formula (I).

In one embodiment, X is O.

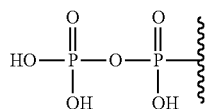
In another embodiment, X is N.

In another embodiment, X is S.

In another embodiment, X is CH₂.

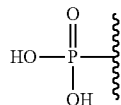
In another embodiment, Y is —C(R⁶)—.

In one embodiment, R¹ is



18

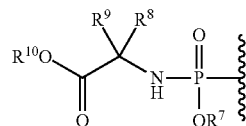
In another embodiment, R¹ is



In another embodiment, R² is —C(O)—(C₁-C₆ alkyl).

In yet another embodiment, R² is —C(O)—CH(CH₃)₂.

In another embodiment, R² is:



In one embodiment, R³ is H.

In another embodiment, R³ is C₁-C₆ haloalkyl.

In yet another embodiment, R³ is C₁-C₆ hydroxyalkyl.

In an additional embodiment, R³ is C₂-C₆ alkynyl.

In another embodiment R³ is C₃-C₇ cycloalkyl.

In another embodiment, R³ is C₁-C₆ alkyl.

In yet another embodiment, R³ is methyl.

In another embodiment, R³ is C₂-C₆ alkenyl.

In another embodiment, R⁴ is —OR¹².

In another embodiment, R⁴ is NHC(O)OR¹².

In yet another embodiment, R⁴ is —NHC(O)N(R¹²)₂.

In another embodiment, R⁴ is NHC(O)R¹².

In one embodiment, R⁵ is NHC(O)OR¹².

In yet another embodiment, R⁵ is —NHC(O)N(R¹²)₂.

In still another embodiment, R⁵ is —OR¹².

In an additional embodiment, R⁵ is —N(R¹²)₂.

In another embodiment, R⁵ is NHC(O)R¹².

In another embodiment, R¹⁸ is C₁-C₆ alkyl.

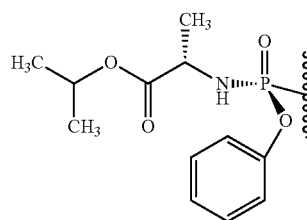
In another embodiment, R¹⁸ is C₁-C₆ alkenyl.

In another embodiment, R¹⁸ is —O(C₁-C₆ alkyl).

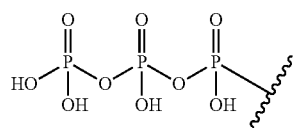
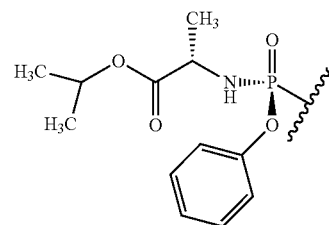
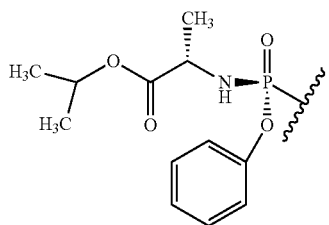
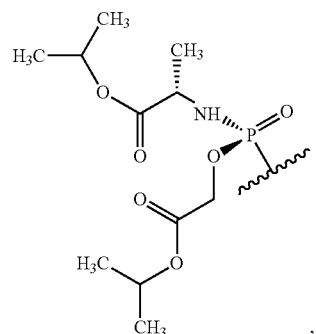
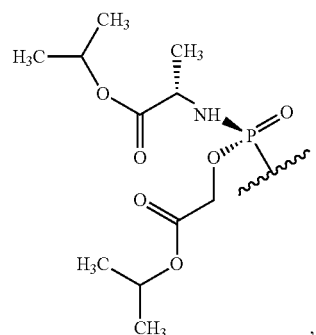
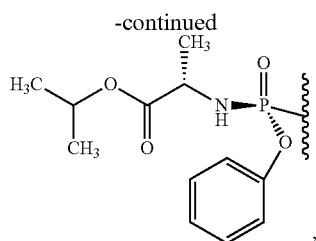
In one embodiment, Y is N or CH, R⁴ is —N(R¹²)₂, and R⁵ is H.

In another embodiment, Y is N or CH, R⁴ is NH₂, and R⁵ is H.

In one embodiment, Y is N or CH, R⁴ is NH₂, R⁵ is H, and R¹ is



19

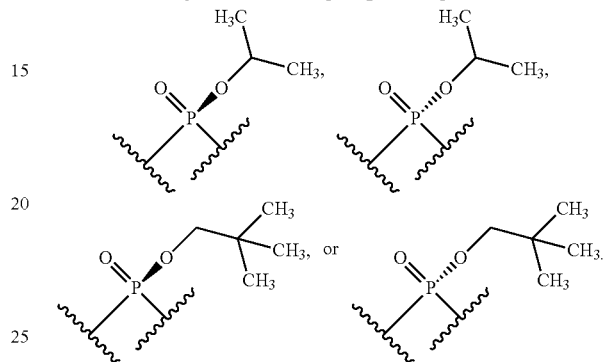


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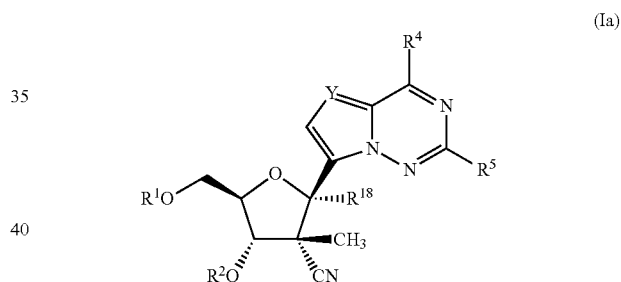
In another embodiment, Y is N or CH, R⁴ is NH₂, R⁵ is H, and R¹ and R² join to form a group having the formula:



In another embodiment, Y is N or CH, R⁴ is NH₂, R⁵ is H, and R¹ and R² join to form a group having the structure:



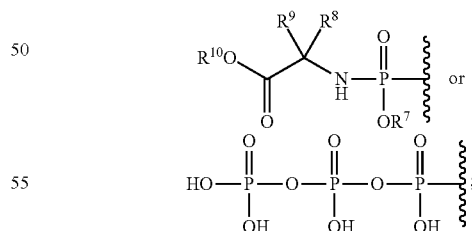
In one embodiment, the compounds of formula (I) have the formula (Ia):



and pharmaceutically acceptable salts thereof,

wherein:

R¹ is H,



R² is H, or R¹ and R² join to form a group having the formula:



21

R^4 is H, OH or $-\text{N}(\text{R}^{12})_2$;

R^5 is H or NH_2 ;

R^{18} is H, $-\text{CN}$ or $-\text{OCH}_3$;

R^7 is $-(\text{C}_1\text{-C}_3 \text{ alkylene})\text{-C}(\text{O})\text{O}-(\text{C}_1\text{-C}_6 \text{ alkyl})$ or phenyl, wherein said phenyl group can be optionally substituted with a halo group;

R^8 and R^9 are each independently H or $\text{C}_1\text{-C}_6$ alkyl;

R^{10} is $\text{C}_1\text{-C}_6$ alkyl; and

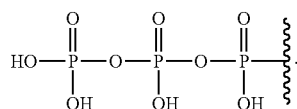
R^{11} is $\text{C}_1\text{-C}_6$ alkyl or $\text{C}_3\text{-C}_7$ cycloalkyl.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), Y is N.

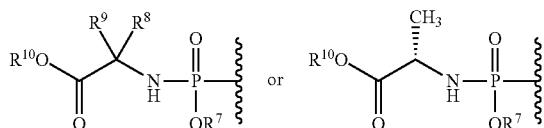
In yet another embodiment, for the compounds of Formula (I) or Formula (Ia), Y is CH.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 is H.

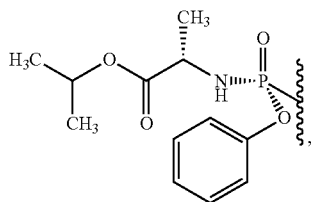
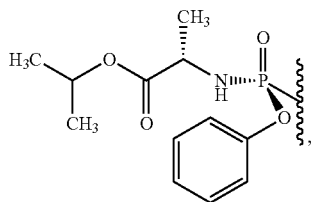
In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 is



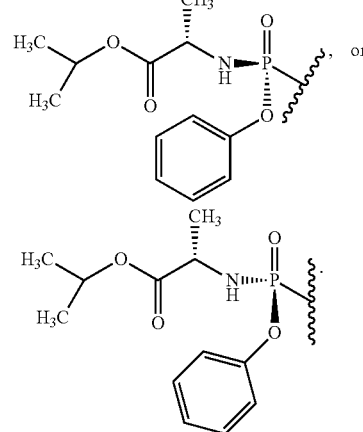
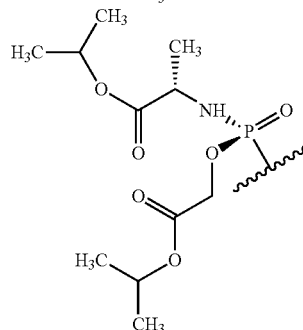
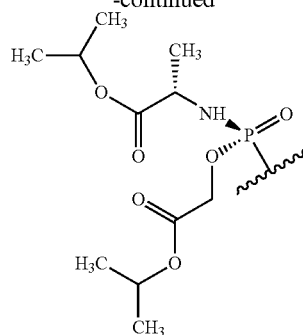
In yet another embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 is



In still another embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 is

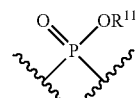
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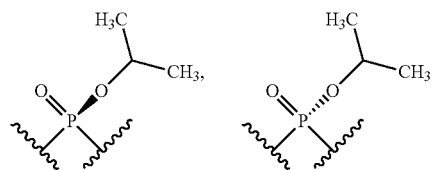


In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^2 is H.

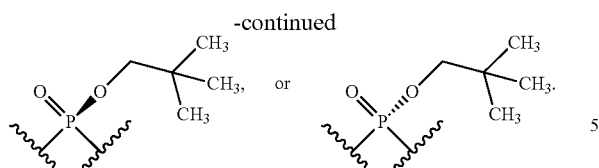
In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 and R^2 join to form a group having the formula:



In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^1 and R^2 join to form a group having the structure:



23



In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^4 is H.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^4 is OH.

In an additional embodiment, for the compounds of Formula (I) or Formula (Ia), R^4 is $-\text{N}(\text{R}^{12})_2$.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^4 is $-\text{NH}_2$.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^5 is H.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^5 is $-\text{NH}_2$.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^{18} is H.

In an additional embodiment, for the compounds of Formula (I) or Formula (Ia), R^{18} is $-\text{OCH}_3$.

In yet another embodiment, for the compounds of Formula (I) or Formula (Ia), R^{18} is CN.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^7 is $-(\text{C}_1\text{-C}_3 \text{ alkylene})-\text{C}(\text{O})\text{O}-(\text{C}_1\text{-C}_6 \text{ alkyl})$.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^7 is phenyl, wherein said phenyl group can be optionally substituted with a halo group.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^8 is H.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^8 is $\text{C}_1\text{-C}_6$ alkyl.

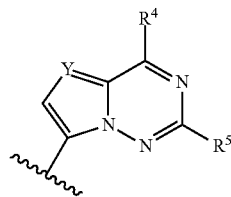
In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^9 is H.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^9 is $\text{C}_1\text{-C}_6$ alkyl.

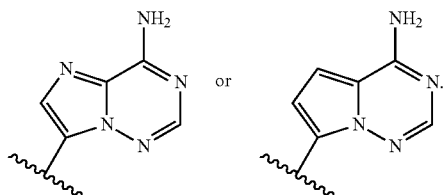
In one embodiment, for the compounds of Formula (I) or Formula (Ia), R^{11} is $\text{C}_1\text{-C}_6$ alkyl.

In another embodiment, for the compounds of Formula (I) or Formula (Ia), R^{11} is $\text{C}_3\text{-C}_7$ cycloalkyl.

In one embodiment, for the compounds of Formula (I) or Formula (Ia), the group:

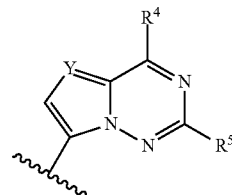


has the structure:

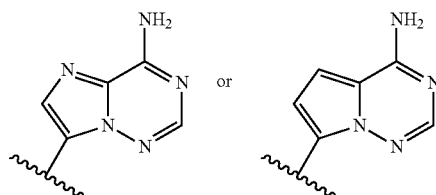


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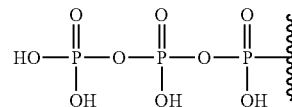
In one embodiment, for the compounds of formula (Ia), R^1 is H, R^2 is H, and the group:



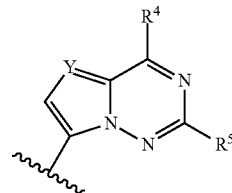
has the structure:



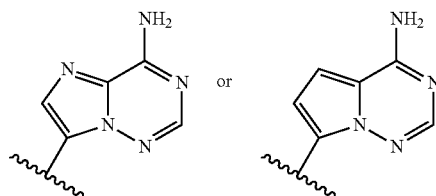
In another embodiment, for the compounds of formula (Ia), R^1 is:



R^2 is H, and the group:

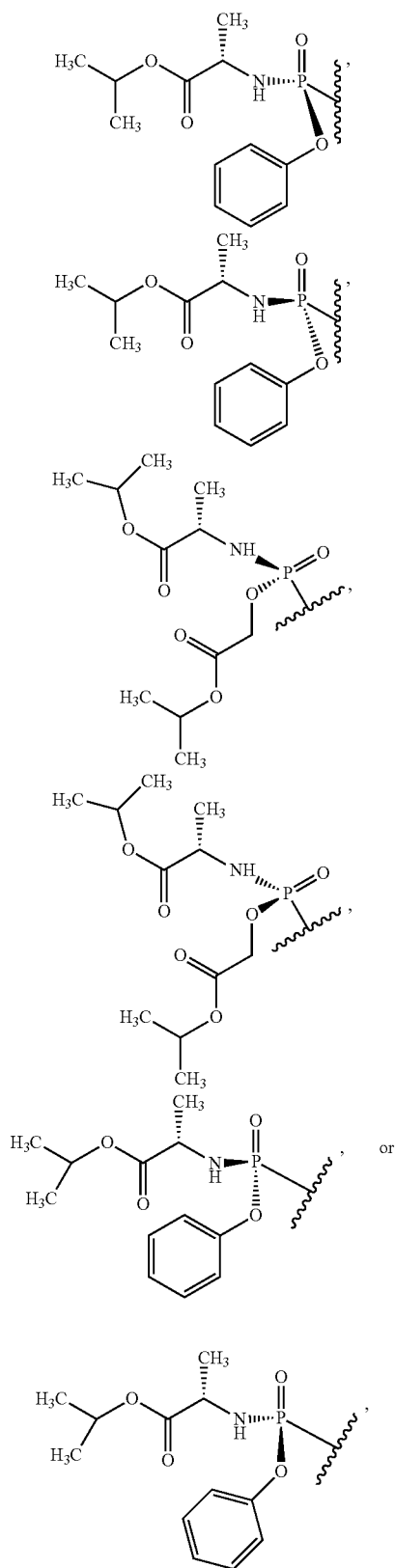


has the structure:

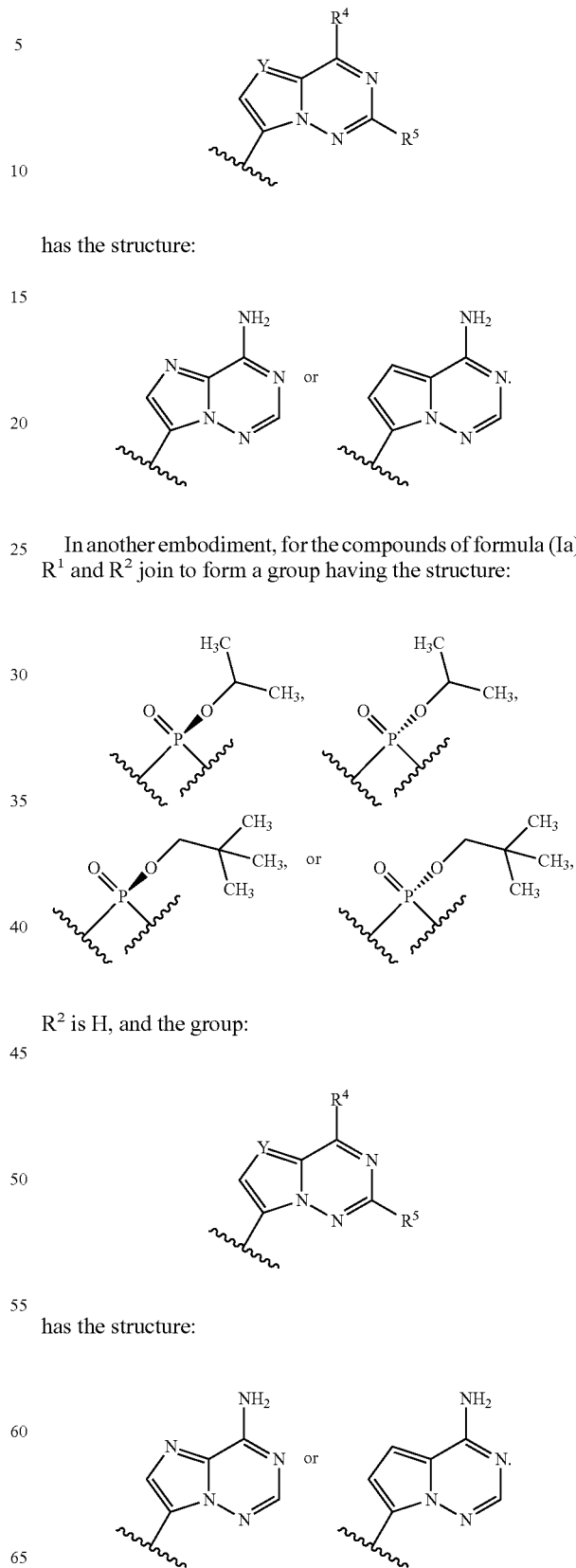


25

In another embodiment, for the compounds of formula (Ia),
 R^1 is:

**26**

R^2 is H, and the group:



27

In embodiments of the invention, variables R^1 , R^2 , R^3 , R^4 , R^5 , and R^{18} for the Compounds of Formula (I) are selected independently of each other.

In another embodiment, the Compounds of Formula (I) are in substantially purified form.

Non-limiting examples of the Compounds of Formula (I) include compounds 1-27 as set forth in the Examples below, and pharmaceutically acceptable salts thereof.

Other embodiments of the present invention include the following:

(a) A pharmaceutical composition comprising an effective amount of a Compound of Formula (I) or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

(b) The pharmaceutical composition of (a), further comprising a second therapeutic agent selected from the group consisting of HCV antiviral agents, immunomodulators, and anti-infective agents.

(c) The pharmaceutical composition of (b), wherein the HCV antiviral agent is an antiviral selected from the group consisting of HCV protease inhibitors, HCV NS5B polymerase inhibitors and HCV NS5A inhibitors.

(d) A pharmaceutical combination that is (i) a Compound of Formula (I) and (ii) a second therapeutic agent selected from the group consisting of HCV antiviral agents, immunomodulators, and anti-infective agents; wherein the Compound of Formula (I) and the second therapeutic agent are each employed in an amount that renders the combination effective for inhibiting HCV replication, or for treating HCV infection and/or reducing the likelihood or severity of symptoms of HCV infection.

(e) The combination of (d), wherein the HCV antiviral agent is an antiviral selected from the group consisting of HCV protease inhibitors, HCV NS5B polymerase inhibitors and HCV NS5A inhibitors.

(f) A method of inhibiting HCV replication in a subject in need thereof which comprises administering to the subject an effective amount of a Compound of Formula (I).

(g) A method of treating HCV infection and/or reducing the likelihood or severity of symptoms of HCV infection in a subject in need thereof which comprises administering to the subject an effective amount of a Compound of Formula (I).

(h) The method of (g), wherein the Compound of Formula (I) is administered in combination with an effective amount of at least one second therapeutic agent selected from the group consisting of HCV antiviral agents, immunomodulators, and anti-infective agents.

(i) The method of (h), wherein the HCV antiviral agent is an antiviral selected from the group consisting of HCV protease inhibitors, HCV NS5B polymerase inhibitors and HCV NS5A inhibitors.

(j) A method of inhibiting HCV replication in a subject in need thereof which comprises administering to the subject the pharmaceutical composition of (a), (b) or (c) or the combination of (d) or (e).

(k) A method of treating HCV infection and/or reducing the likelihood or severity of symptoms of HCV infection in a subject in need thereof which comprises administering to the subject the pharmaceutical composition of (a), (b) or (c) or the combination of (d) or (e).

Additional embodiments of the invention include the pharmaceutical compositions, combinations and methods set forth in (a)-(k) above and the uses set forth below, wherein the compound of the present invention employed therein is a compound of one of the embodiments, aspects, classes, subclasses, or features of the compounds described above. In all of these embodiments, the compound may optionally be used

28

in the form of a pharmaceutically acceptable salt or hydrate as appropriate. It is understood that references to compounds would include the compound in its present form as well as in different forms, such as polymorphs, solvates and hydrates, as applicable.

It is further to be understood that the embodiments of compositions and methods provided as (a) through (k) above are understood to include all embodiments of the compounds, including such embodiments as result from combinations of embodiments.

Uses of the 2'-Cyano Substituted Nucleoside Derivatives

The 2'-Cyano Substituted Nucleoside Derivatives are useful in human and veterinary medicine for treating or preventing a viral infection in a patient. In one embodiment, the 2'-Cyano Substituted Nucleoside Derivatives can be inhibitors of viral replication. In another embodiment, the 2'-Cyano Substituted Nucleoside Derivatives can be inhibitors of HCV replication. Accordingly, the 2'-Cyano Substituted Nucleoside Derivatives are useful for treating viral infections, such as HCV. In accordance with the invention, the 2'-Cyano Substituted Nucleoside Derivatives can be administered to a patient in need of treatment or prevention of a viral infection.

The present invention also includes a compound of the present invention for use (i) in, (ii) as a medicament for, or (iii) in the preparation of a medicament for: (a) medicine, (b) inhibiting HCV replication or (c) treating HCV infection and/or reducing the likelihood or severity of symptoms of HCV infection. In these uses, the compounds of the present invention can optionally be employed in combination with one or more second therapeutic agents selected from HCV antiviral agents, anti-infective agents, and immunomodulators.

Accordingly, in one embodiment, the invention provides methods for treating a viral infection in a patient comprising administering to the patient an effective amount of at least one 2'-Cyano Substituted Nucleoside Derivative or a pharmaceutically acceptable salt thereof.

The 2'-Cyano Substituted Nucleoside Derivatives are also useful in the preparation and execution of screening assays for antiviral compounds. For example the 2'-Cyano Substituted Nucleoside Derivatives are useful for identifying resistant HCV replicon cell lines harboring mutations within NS5B, which are excellent screening tools for more powerful antiviral compounds. Furthermore, the 2'-Cyano Substituted Nucleoside Derivatives are useful in establishing or determining the binding site of other antivirals to the HCV NS5B polymerase.

In addition, the triphosphate forms of the 2'-Cyano Substituted Nucleoside Derivative compounds of the invention can inhibit NS5B enzymatic activity. Non-triphosphate forms of the compounds of the invention may provide a starting point for phosphorylation.

Treatment or Prevention of HCV Infection:

The 2'-Cyano Substituted Nucleoside Derivatives are useful in the inhibition of HCV, the treatment of HCV infection and/or reduction of the likelihood or severity of symptoms of HCV infection and the inhibition of HCV viral replication and/or HCV viral production in a cell-based system. For example, the 2'-Cyano Substituted Nucleoside Derivatives are useful in treating infection by HCV after suspected past exposure to HCV by such means as blood transfusion, exchange of body fluids, bites, accidental needle stick, or exposure to patient blood during surgery or other medical procedures.

In one embodiment, the hepatitis C infection is acute hepatitis C. In another embodiment, the hepatitis C infection is chronic hepatitis C.

Accordingly, in one embodiment, the invention provides methods for treating HCV infection in a patient, the methods comprising administering to the patient an effective amount of at least one 2'-Cyano Substituted Nucleoside Derivative or a pharmaceutically acceptable salt thereof. In a specific embodiment, the amount administered is effective to treat or prevent infection by HCV in the patient. In another specific embodiment, the amount administered is effective to inhibit HCV viral replication and/or viral production in the patient.

The compositions and combinations of the present invention can be useful for treating a patient suffering from infection related to any HCV genotype. HCV types and subtypes may differ in their antigenicity, level of viremia, severity of disease produced, and response to interferon therapy as described in Holland et al., *Pathology*, 30(2):192-195 (1998). The nomenclature set forth in Simmonds et al., *J Gen Virol*, 74(Pt11):2391-2399 (1993) is widely used and classifies isolates into six major genotypes, 1 through 6, with two or more related subtypes, e.g., 1a and 1b.

Combination Therapy:

In another embodiment, the present methods for treating or preventing HCV infection can further comprise the administration of one or more additional therapeutic agents which are not 2'-Cyano Substituted Nucleoside Derivatives.

In one embodiment, the additional therapeutic agent is an antiviral agent.

In another embodiment, the additional therapeutic agent is an immunomodulatory agent, such as an immunosuppressive agent.

Accordingly, in one embodiment, the present invention provides methods for treating a viral infection in a patient, the method comprising administering to the patient: (i) at least one 2'-Cyano Substituted Nucleoside Derivative, or a pharmaceutically acceptable salt thereof, and (ii) at least one additional therapeutic agent that is other than a 2'-Cyano Substituted Nucleoside Derivative, wherein the amounts administered are together effective to treat or prevent a viral infection.

When administering a combination therapy of the invention to a patient, therapeutic agents in the combination, or a pharmaceutical composition or compositions comprising therapeutic agents, may be administered in any order such as, for example, sequentially, concurrently, together, simultaneously and the like. The amounts of the various actives in such combination therapy may be different amounts (different dosage amounts) or same amounts (same dosage amounts). Thus, for non-limiting illustration purposes, a 2'-Cyano Substituted Nucleoside Derivative and an additional therapeutic agent may be present in fixed amounts (dosage amounts) in a single dosage unit (e.g., a capsule, a tablet and the like).

In one embodiment, the at least one 2'-Cyano Substituted Nucleoside Derivative is administered during a time when the additional therapeutic agent(s) exert their prophylactic or therapeutic effect, or vice versa.

In another embodiment, the at least one 2'-Cyano Substituted Nucleoside Derivative and the additional therapeutic agent(s) are administered in doses commonly employed when such agents are used as monotherapy for treating a viral infection.

In another embodiment, the at least one 2'-Cyano Substituted Nucleoside Derivative and the additional therapeutic agent(s) are administered in doses lower than the doses commonly employed when such agents are used as monotherapy for treating a viral infection.

In still another embodiment, the at least one 2'-Cyano Substituted Nucleoside Derivative and the additional thera-

peutic agent(s) act synergistically and are administered in doses lower than the doses commonly employed when such agents are used as monotherapy for treating a viral infection.

In one embodiment, the at least one 2'-Cyano Substituted Nucleoside Derivative and the additional therapeutic agent(s) are present in the same composition. In one embodiment, this composition is suitable for oral administration. In another embodiment, this composition is suitable for intravenous administration. In another embodiment, this composition is suitable for subcutaneous administration. In still another embodiment, this composition is suitable for parenteral administration.

Viral infections and virus-related disorders that can be treated or prevented using the combination therapy methods of the present invention include, but are not limited to, those listed above.

In one embodiment, the viral infection is HCV infection.

The at least one 2'-Cyano Substituted Nucleoside Derivative and the additional therapeutic agent(s) can act additively or synergistically. A synergistic combination may allow the use of lower dosages of one or more agents and/or less frequent administration of one or more agents of a combination therapy. A lower dosage or less frequent administration of one or more agents may lower toxicity of therapy without reducing the efficacy of therapy.

In one embodiment, the administration of at least one 2'-Cyano Substituted Nucleoside Derivative and the additional therapeutic agent(s) may inhibit the resistance of a viral infection to these agents.

Non-limiting examples of additional therapeutic agents useful in the present compositions and methods include an interferon, an immunomodulator, a viral replication inhibitor, an antisense agent, a therapeutic vaccine, a viral polymerase inhibitor, a nucleoside inhibitor, a viral protease inhibitor, a viral helicase inhibitor, a virion production inhibitor, a viral entry inhibitor, a viral assembly inhibitor, an antibody therapy (monoclonal or polyclonal), and any agent useful for treating an RNA-dependent polymerase-related disorder.

In one embodiment, one or more compounds of the invention are administered with one or more additional therapeutic agents, including but not limited to the therapeutic agents described, supra.

In one embodiment, the additional therapeutic agent is a viral protease inhibitor.

In another embodiment, the additional therapeutic agent is a viral replication inhibitor.

In another embodiment, the additional therapeutic agent is an HCV NS3 protease inhibitor.

In still another embodiment, the additional therapeutic agent is an HCV NS5B polymerase inhibitor.

In another embodiment, the additional therapeutic agent is a nucleoside inhibitor.

In another embodiment, the additional therapeutic agent is an interferon.

In yet another embodiment, the additional therapeutic agent is an HCV replicase inhibitor.

In another embodiment, the additional therapeutic agent is an antisense agent.

In another embodiment, the additional therapeutic agent is a therapeutic vaccine.

In a further embodiment, the additional therapeutic agent is a virion production inhibitor.

In another embodiment, the additional therapeutic agent is an antibody therapy.

In another embodiment, the additional therapeutic agent is an HCV NS2 inhibitor.

31

In still another embodiment, the additional therapeutic agent is an HCV NS4A inhibitor.

In another embodiment, the additional therapeutic agent is an HCV NS4B inhibitor.

In another embodiment, the additional therapeutic agent is an HCV NS5A inhibitor.

In yet another embodiment, the additional therapeutic agent is an HCV NS3 helicase inhibitor.

In another embodiment, the additional therapeutic agent is an HCV IRES inhibitor.

In another embodiment, the additional therapeutic agent is an HCV p7 inhibitor.

In a further embodiment, the additional therapeutic agent is an HCV entry inhibitor.

In another embodiment, the additional therapeutic agent is an HCV assembly inhibitor.

In another embodiment, one or more compounds of the present invention are administered with one additional therapeutic agent selected from an HCV protease inhibitor, an interferon, a pegylated interferon and ribavirin. In another embodiment, one or more compounds of the present invention are administered with one additional therapeutic agent selected from an HCV polymerase inhibitor, a viral protease inhibitor, an interferon, and a viral replication inhibitor. In another embodiment, one or more compounds of the present invention are administered with ribavirin.

In still another embodiment, one or more compounds of the present invention are administered with two additional therapeutic agents selected from an HCV protease inhibitor, an HCV replication inhibitor, a nucleoside, an interferon, a pegylated interferon and ribavirin.

In another embodiment, one or more compounds of the present invention are administered with an HCV protease inhibitor and ribavirin. In another specific embodiment, one or more compounds of the present invention are administered with a pegylated interferon and ribavirin.

In another embodiment, one or more compounds of the present invention are administered with three additional therapeutic agents selected from an HCV protease inhibitor, an HCV replication inhibitor, a nucleoside, an interferon, a pegylated interferon and ribavirin.

In one embodiment, one or more compounds of the present invention are administered with two additional therapeutic agents selected from an HCV polymerase inhibitor, a viral protease inhibitor, an interferon, and a viral replication inhibitor.

In another embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and another therapeutic agent.

In another embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and another therapeutic agent, wherein the additional therapeutic agent is selected from an HCV polymerase inhibitor, a viral protease inhibitor, and a viral replication inhibitor.

In still another embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and a viral protease inhibitor.

In another embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and an HCV protease inhibitor.

In another embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and boceprevir or telaprevir.

32

In a further embodiment, one or more compounds of the present invention are administered with ribavirin, interferon and an HCV polymerase inhibitor.

In another embodiment, one or more compounds of the present invention are administered with pegylated-interferon alpha and ribavirin.

In one embodiment, the additional therapeutic agents comprise a viral protease inhibitor and a viral polymerase inhibitor.

In still another embodiment, the additional therapeutic agents comprise a viral protease inhibitor and an immunomodulatory agent.

In yet another embodiment, the additional therapeutic agents comprise a polymerase inhibitor and an immunomodulatory agent.

In another embodiment, the additional therapeutic agents comprise a viral protease inhibitor and a nucleoside.

In another embodiment, the additional therapeutic agents comprise an immunomodulatory agent and a nucleoside.

In one embodiment, the additional therapeutic agents comprise an HCV protease inhibitor and an HCV polymerase inhibitor.

In another embodiment, the additional therapeutic agents comprise a nucleoside and an HCV NS5A inhibitor.

In another embodiment, the additional therapeutic agents comprise a viral protease inhibitor, an immunomodulatory agent and a nucleoside.

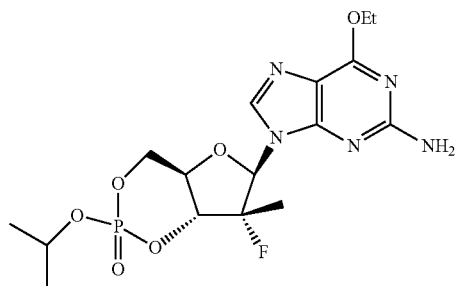
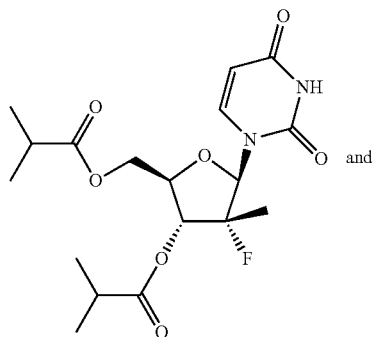
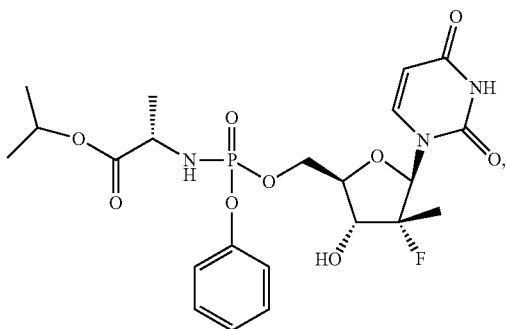
In a further embodiment, the additional therapeutic agents comprise a viral protease inhibitor, a viral polymerase inhibitor and an immunomodulatory agent.

In another embodiment, the additional therapeutic agent is ribavirin.

HCV polymerase inhibitors useful in the present compositions and methods include, but are not limited to, VP-19744 (Wyeth/ViroPharma), PSI-7851 (Pharmasset), RG7128 (Roche/Pharmasset), PSI-7977 (Pharmasset), PSI-938 (Pharmasset), PSI-879 (Pharmasset), PSI-661 (Pharmasset), PF-868554/filibuvir (Pfizer), VCH-759NX-759 (ViroChem Pharma/Vertex), HCV-371 (Wyeth/ViroPharma), HCV-796 (Wyeth/ViroPharma), IDX-184 (Idenix), IDX-375 (Idenix), NM-283 (Idenix/Novartis), GL-60667 (Genelabs), JTK-109 (Japan Tobacco), PSI-6130 (Pharmasset), R1479 (Roche), R-1626 (Roche), R-7128 (Roche), MK-0608 (Isis/Merck), INX-8014 (Inhibitex), INX-8018 (Inhibitex), INX-189 (Inhibitex), GS 9190 (Gilead), A-848837 (Abbott), ABT-333 (Abbott), ABT-072 (Abbott), A-837093 (Abbott), BI-207127 (Boehringer-Ingelheim), BILB-1941 (Boehringer-Ingelheim), MK-3281 (Merck), VCH-222/VX-222 (ViroChem/Vertex), VCH-916 (ViroChem), VCH-716 (ViroChem), GSK-71185 (Glaxo SmithKline), ANA598 (Anadys), GSK-625433 (Glaxo SmithKline), XTL-2125 (XTL Biopharmaceuticals), and those disclosed in Ni et al., *Current Opinion in Drug Discovery and Development*, 7(4):446 (2004); Tan et al., *Nature Reviews*, 1:867 (2002); and Beaulieu et al., *Current Opinion in Investigational Drugs*, 5:838 (2004).

Other HCV polymerase inhibitors useful in the present compositions and methods include, but are not limited to, those disclosed in International Publication Nos. WO 08/082484, WO 08/082488, WO 08/083351, WO 08/136815, WO 09/032116, WO 09/032123, WO 09/032124 and WO 09/032125; and the following compounds:

33



and pharmaceutically acceptable salts thereof.

Interferons useful in the present compositions and methods include, but are not limited to, interferon alfa-2a, interferon alfa-2b, interferon alfacon-1 and petroleum etherG-interferon alpha conjugates. "PEG-interferon alpha conjugates" are interferon alpha molecules covalently attached to a petroleum etherG molecule. Illustrative petroleum etherG-interferon alpha conjugates include interferon alpha-2a (Roferon™, Hoffman La-Roche, Nutley, N.J.) in the form of pegylated interferon alpha-2a (e.g., as sold under the trade name Pegasys™), interferon alpha-2b (Intron™, from Schering-Plough Corporation) in the form of pegylated interferon alpha-2b (e.g., as sold under the trade name petroleum etherG-Intron™ from Schering-Plough Corporation), interferon alpha-2b-XL (e.g., as sold under the trade name petroleum etherG-Intron™), interferon alpha-2c (Berofer Alpha™, Boehringer Ingelheim, Ingelheim, Germany), petroleum etherG-interferon lambda (Bristol-Myers Squibb and ZymoGenetics), interferon alpha-2b alpha fusion polypeptides, interferon fused with the human blood protein albumin (Albuferon™, Human Genome Sciences), Omega Interferon (Intarcia), Locteron controlled release interferon (Biolex/OctoPlus), Biomed-510 (omega interferon), Peg-IL-29 (ZymoGenetics), Locteron CR (Octopus), R-7025 (Roche), IFN-α-

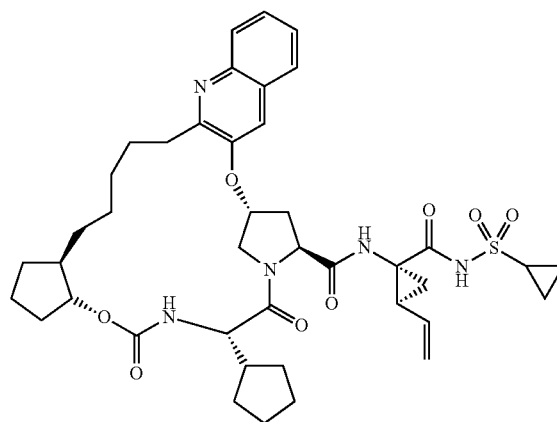
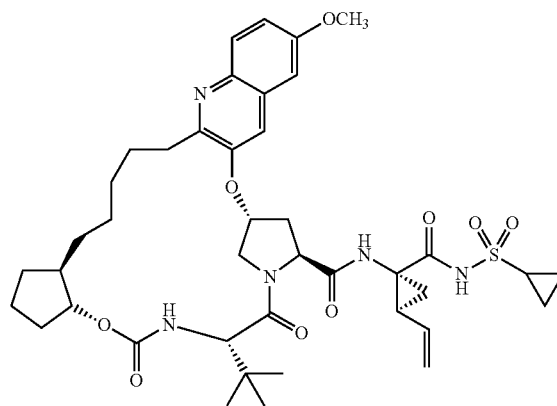
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2b-XL (Flamel Technologies), belerofon (Nautilus) and consensus interferon as defined by determination of a consensus sequence of naturally occurring interferon alphas (Infergen™, Amgen, Thousand Oaks, Calif.).

Examples of viral protease inhibitors useful in the present compositions and methods include, but are not limited to, an HCV protease inhibitor.

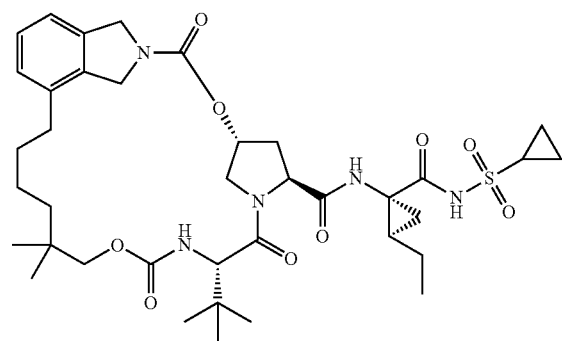
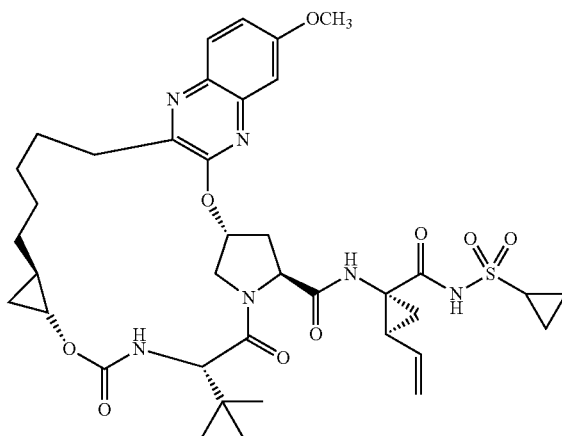
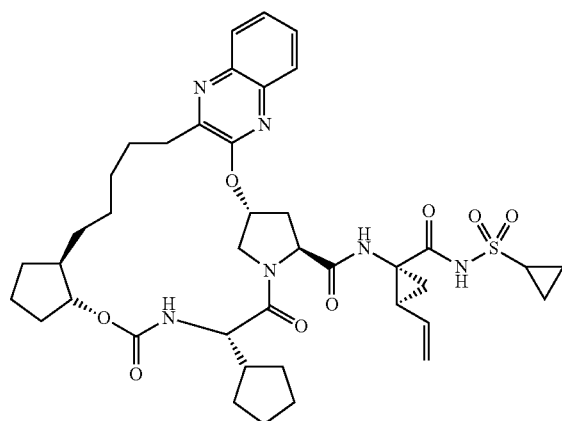
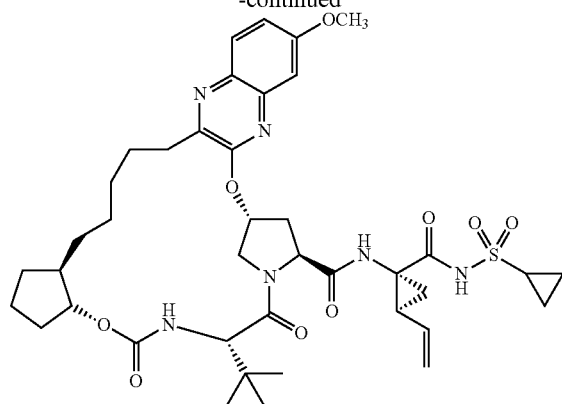
Examples of HCV protease inhibitors useful in the present compositions and methods include, but are not limited to, VX-950 (Telaprevir, Vertex), VX-500 (Vertex), VX-813 (Vertex), VBY-376 (Virobay), BI-201335 (Boehringer Ingelheim), TMC-435 (Medivir/Tibotec), ABT-450 (Abbott/Enanta), TMC-435350 (Medivir), RG7227 (Danoprevir, InterMune/Roche), EA-058 (Abbott/Enanta), EA-063 (Abbott/Enanta), GS-9256 (Gilead), IDX-320 (Idenix), ACH-1625 (Achillion), ACH-2684 (Achillion), GS-9132 (Gilead/Achillion), ACH-1095 (Gilead/Achillion), IDX-136 (Idenix), IDX-316 (Idenix), ITMN-8356 (InterMune), ITMN-8347 (InterMune), ITMN-8096 (InterMune), ITMN-7587 (InterMune), BMS-650032 (Bristol-Myers Squibb), VX-985 (Vertex) and PHX1766 (Phenomix).

Further examples of HCV protease inhibitors useful in the present compositions and methods include, but are not limited to, the following compounds:

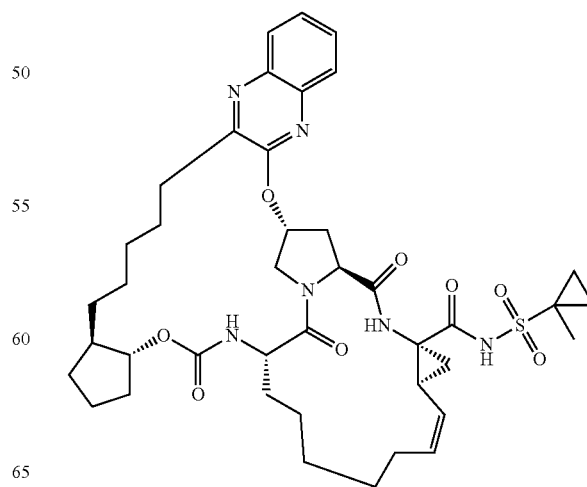
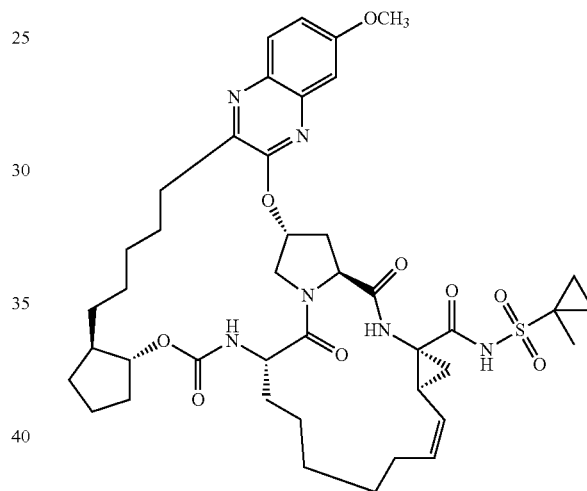
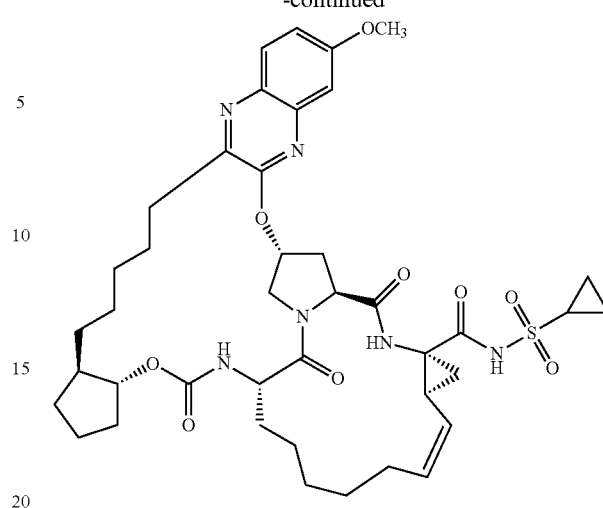


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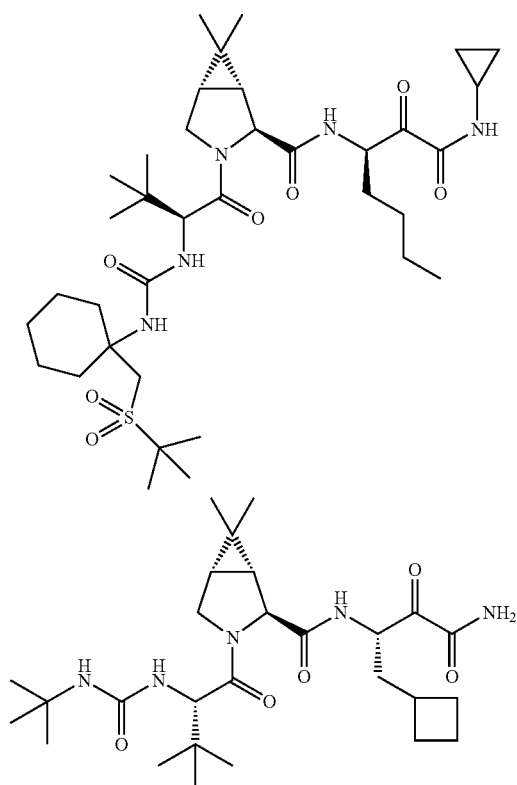
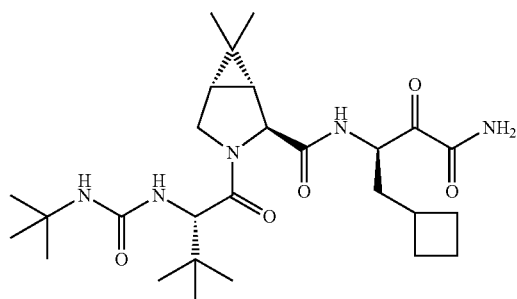
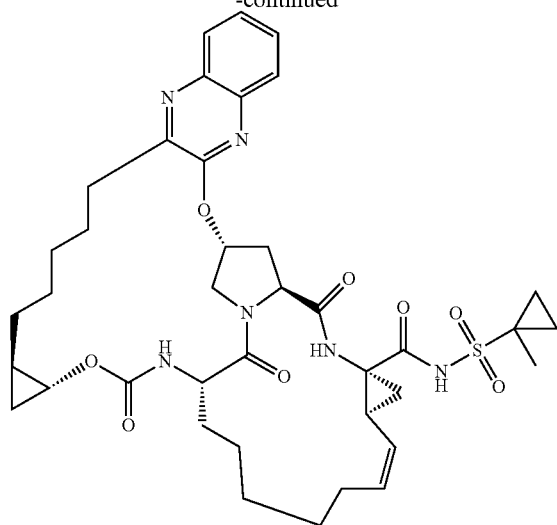
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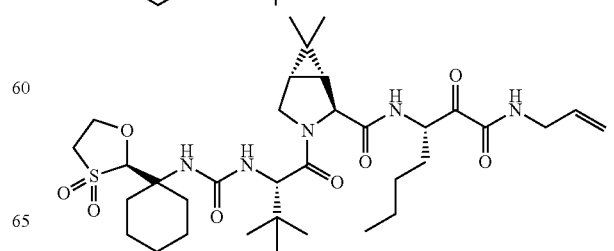
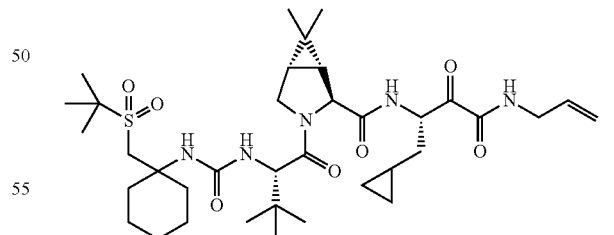
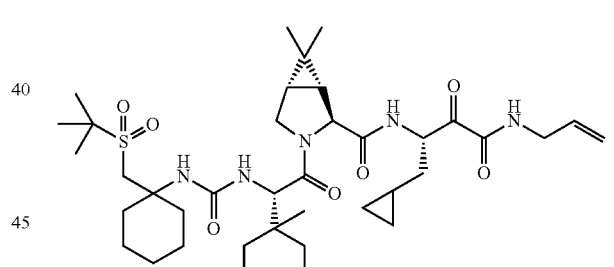
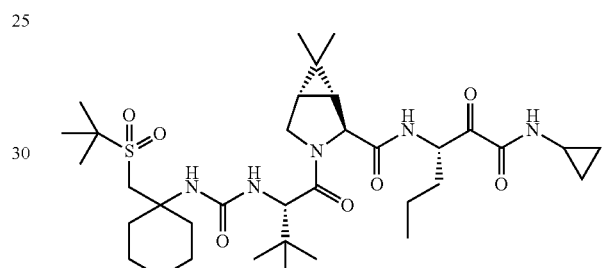
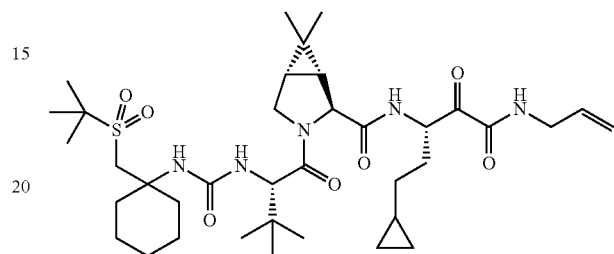
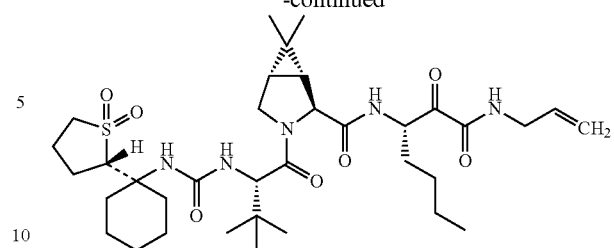


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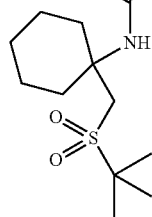
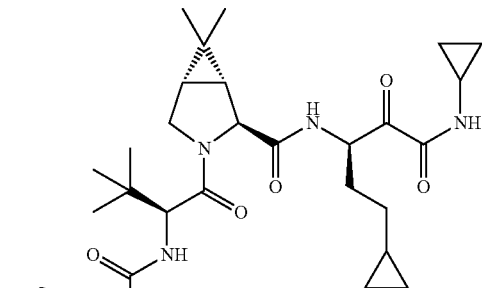
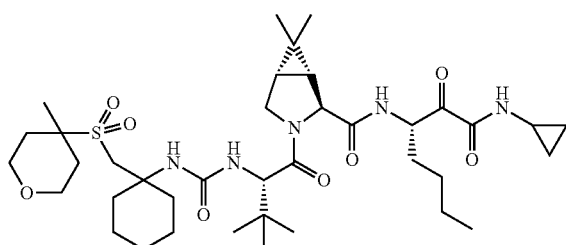
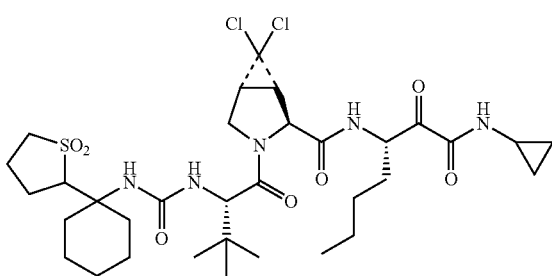
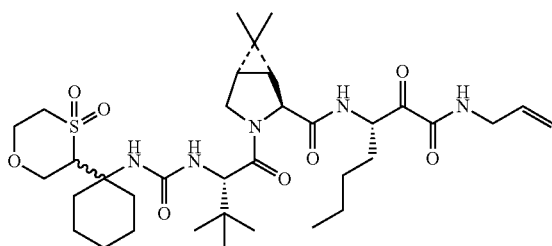
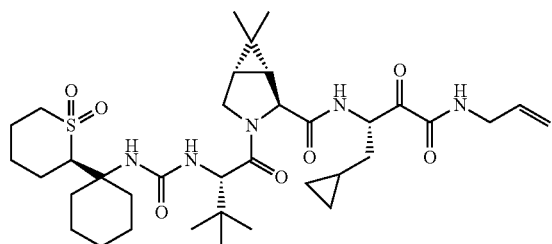
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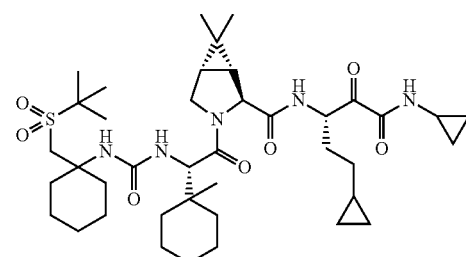
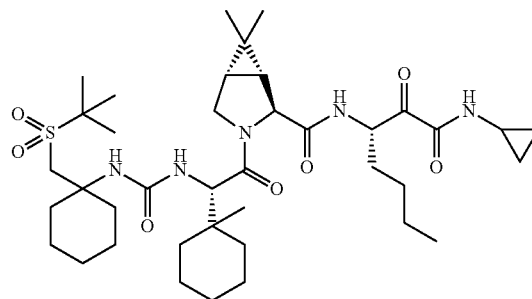
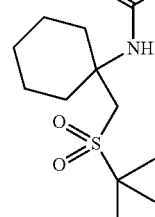
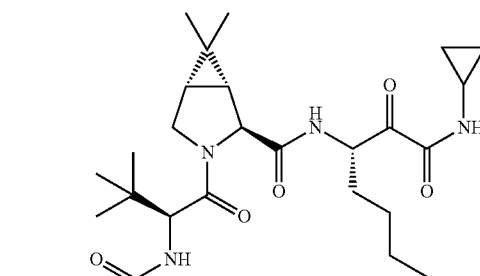
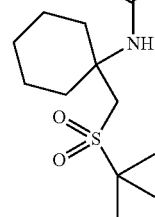
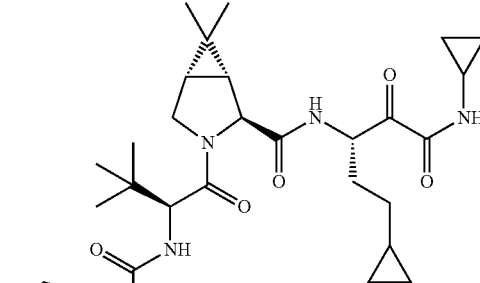


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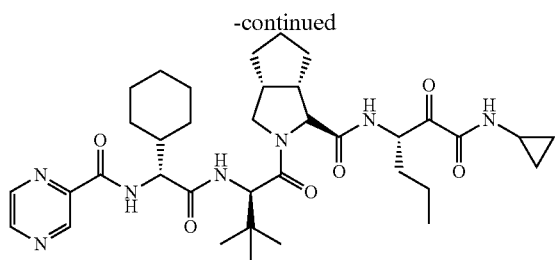
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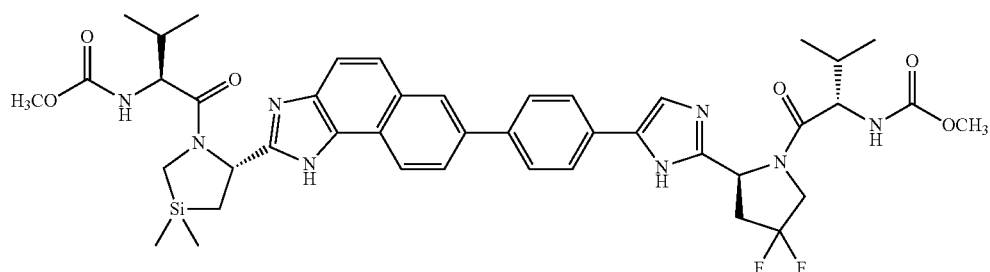
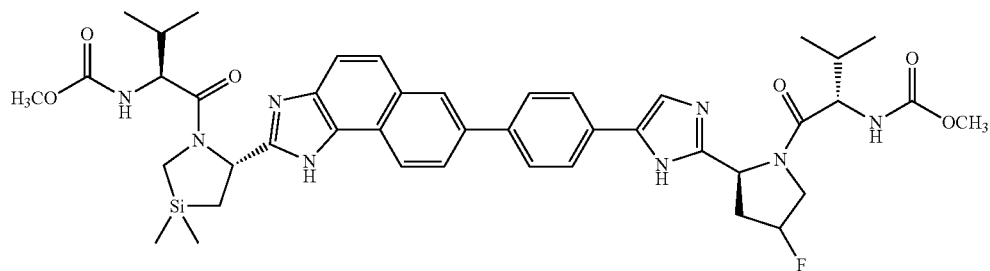
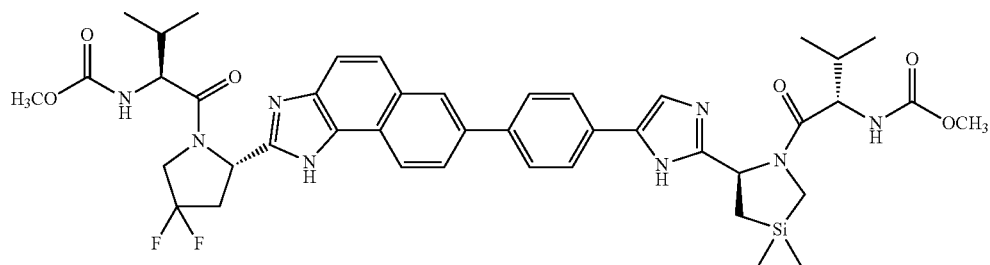
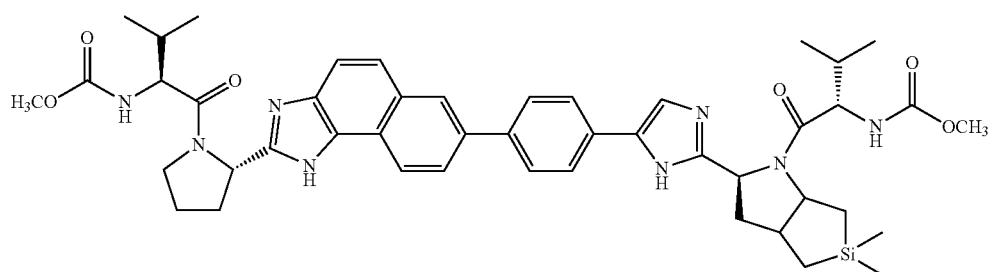
and pharmaceutically acceptable salts thereof.

Viral replication inhibitors useful in the present compositions and methods include, but are not limited to, HCV replicase inhibitors, IRES inhibitors, NS4A inhibitors, NS3 heli-

42

case inhibitors, NS5A inhibitors, NS5B inhibitors, ribavirin, AZD-2836 (Astra Zeneca), viramidine, A-831 (Arrow Therapeutics), EDP-239 (Enanta), ACH-2928 (Achillion), GS-5885 (Gilead); an antisense agent or a therapeutic vaccine.

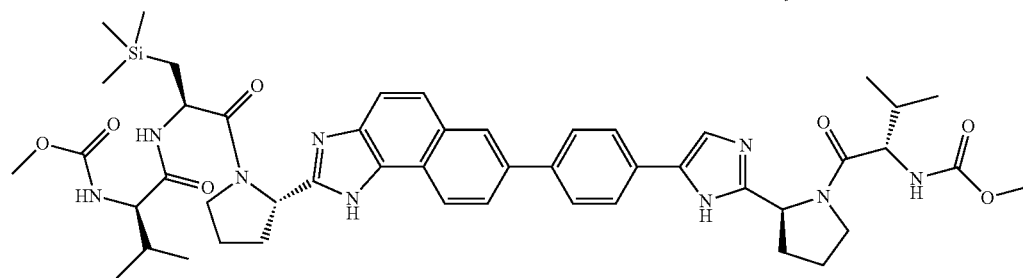
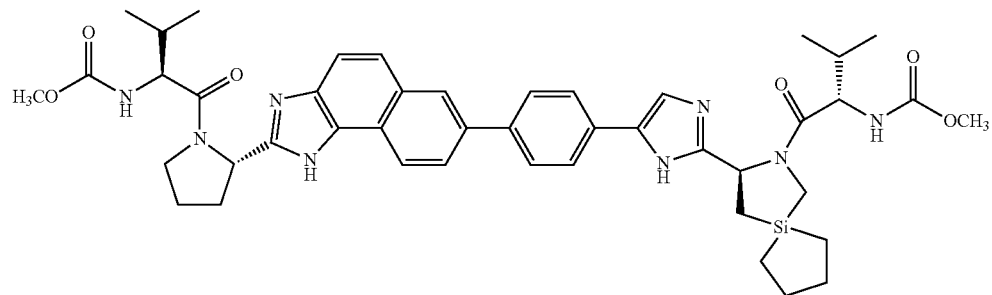
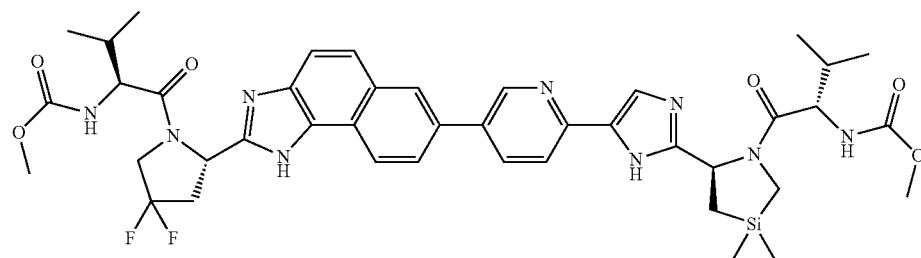
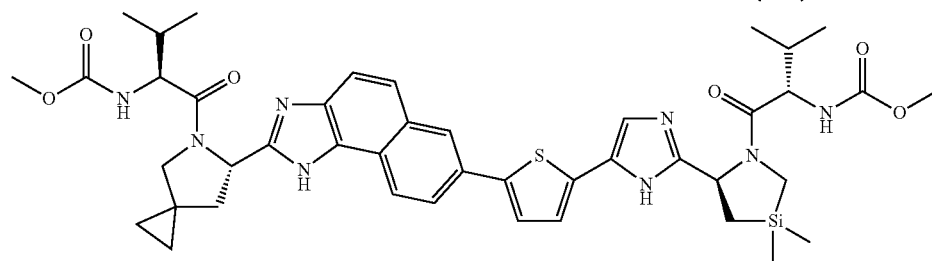
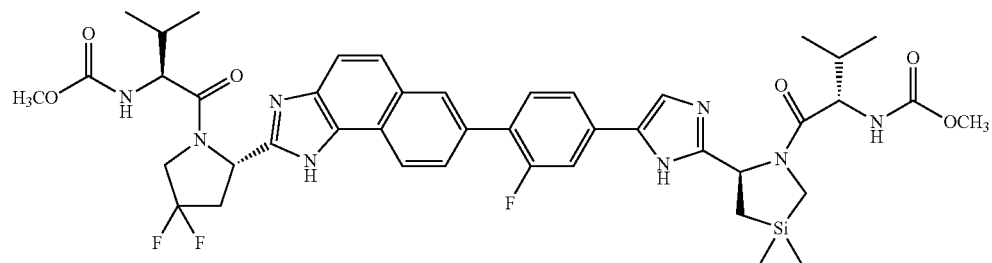
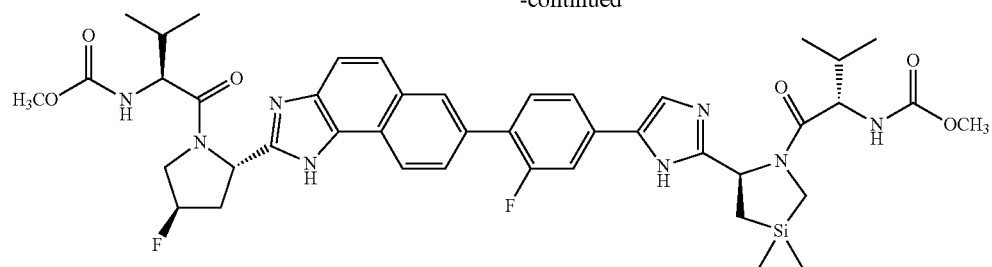
HCV NS5A inhibitors useful in the present compositions and methods include, but are not limited to, ACH-2928 (Achillion), A-832 (Arrow Therapeutics), AZD-7295 (Astra Zeneca/Arrow), GS-5885 (Gilead), PPI-461 (Presidio), PPI-1301 (Presidio), BMS-824383 (Bristol-Myers Squibb) and BMS-790052 (Bristol-Myers Squibb). Additional HCV NS5A inhibitors useful as second additional therapeutic agents in the present compositions and methods include, but are not limited to those disclosed in International Publication No. WO 2010/111483 and the following compounds:



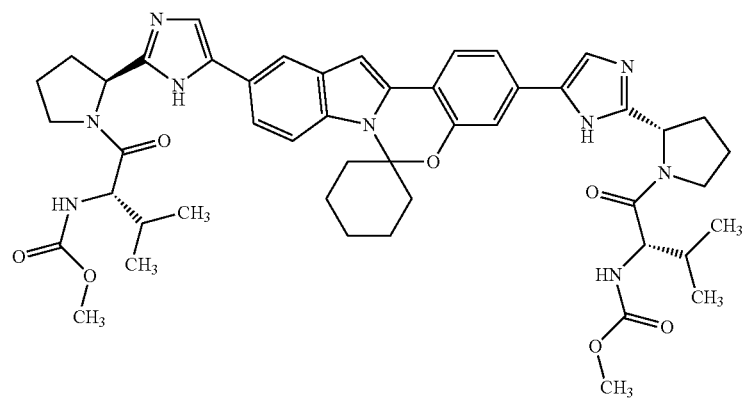
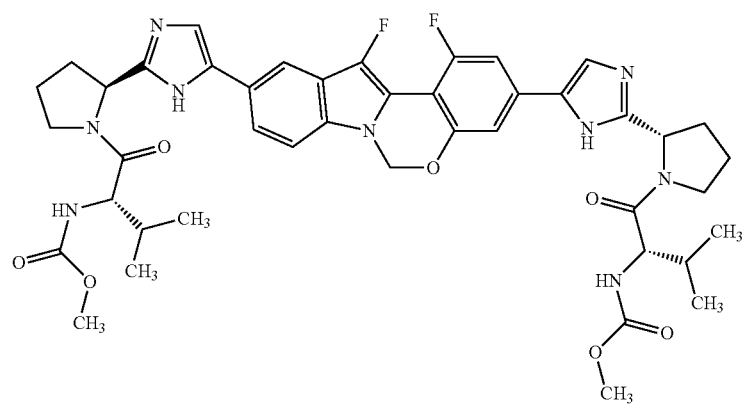
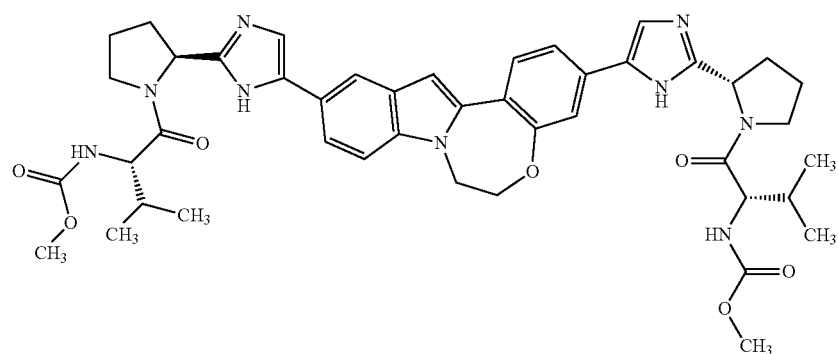
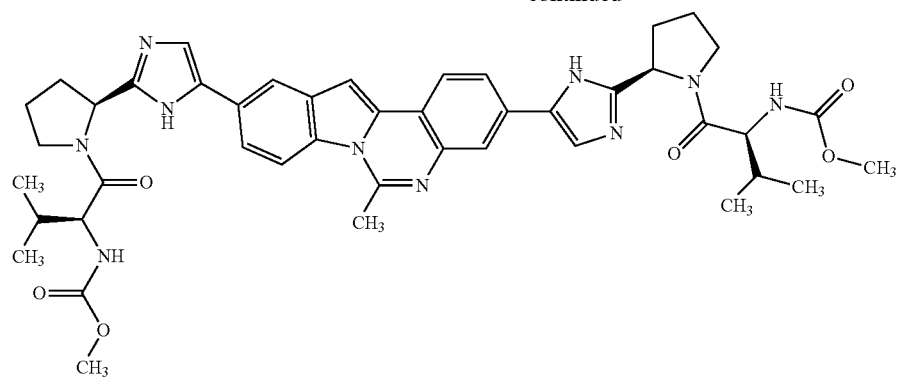
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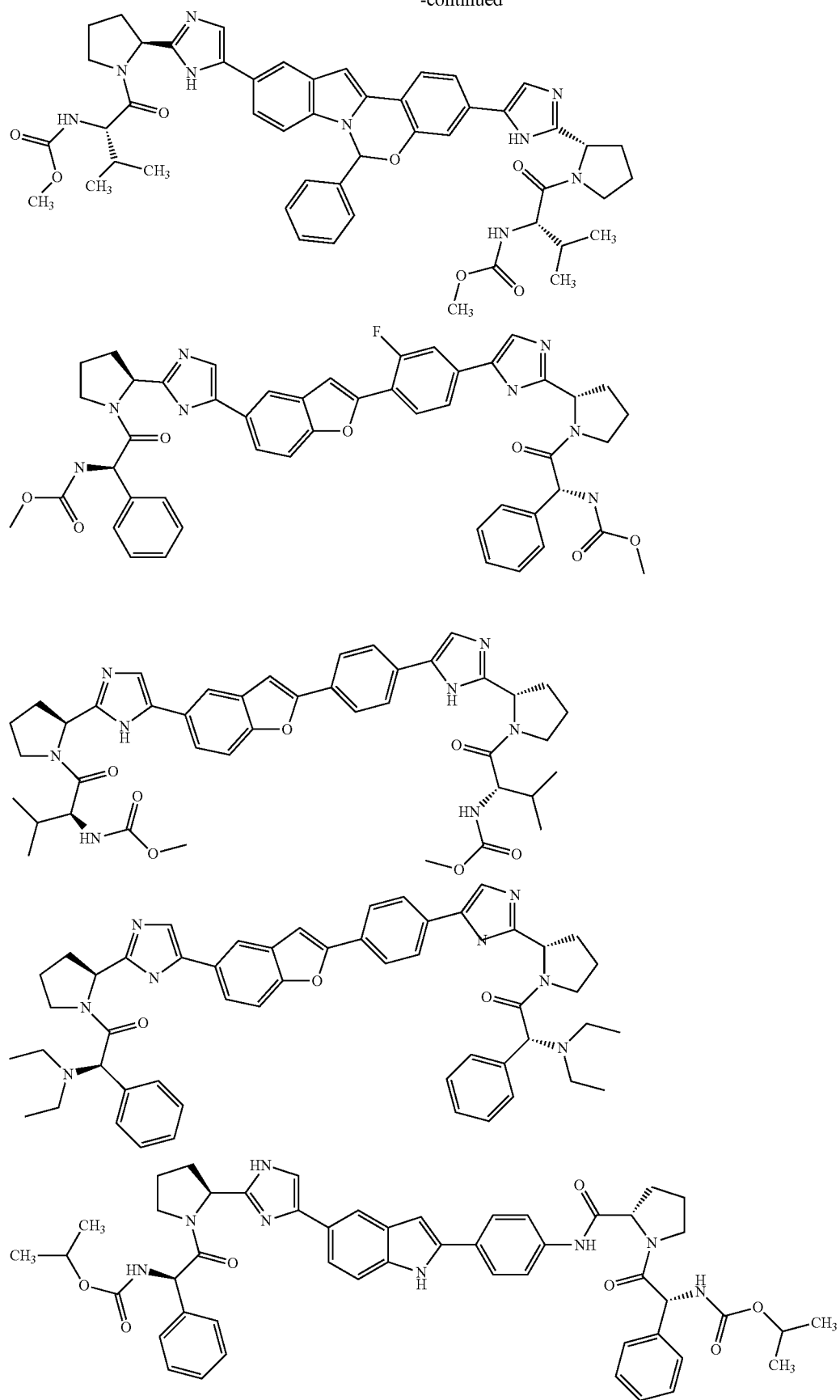
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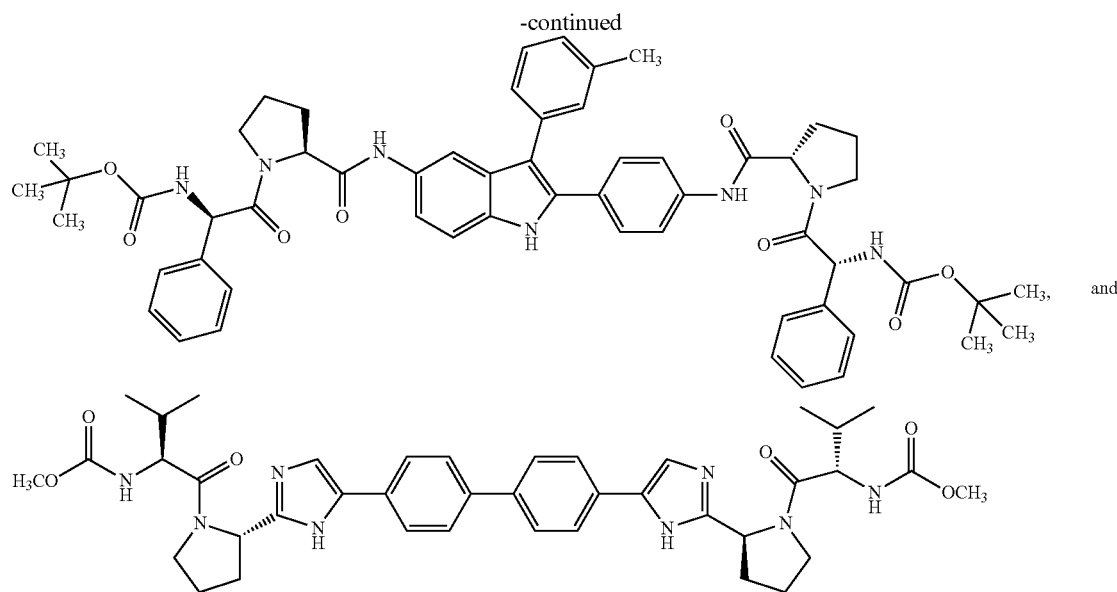


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and pharmaceutically acceptable salts thereof.

HCV replicase inhibitors useful in the present compositions and methods include, but are not limited to, those disclosed in U.S. Patent Publication No. US20090081636.

The doses and dosage regimen of the other agents used in the combination therapies of the present invention for the treatment or prevention of HCV infection can be determined by the attending clinician, taking into consideration the approved doses and dosage regimen in the package insert; the age, sex and general health of the patient; and the type and severity of the viral infection or related disease or disorder. When administered in combination, the 2'-Cyano Substituted Nucleoside Derivative(s) and the other agent(s) can be administered simultaneously (i.e., in the same composition or in separate compositions one right after the other) or sequentially. This particularly useful when the components of the combination are given on different dosing schedules, e.g., one component is administered once daily and another component is administered every six hours, or when the preferred pharmaceutical compositions are different, e.g., one is a tablet and one is a capsule. A kit comprising the separate dosage forms is therefore advantageous.

Generally, a total daily dosage of the at least one 2'-Cyano Substituted Nucleoside Derivative(s) alone, or when administered as combination therapy, can range from about 1 to about 2500 mg per day, although variations will necessarily occur depending on the target of therapy, the patient and the route of administration. In one embodiment, the dosage is from about 10 to about 1000 mg/day, administered in a single dose or in 2-4 divided doses. In another embodiment, the dosage is from about 1 to about 500 mg/day, administered in a single dose or in 2-4 divided doses. In still another embodiment, the dosage is from about 1 to about 100 mg/day, administered in a single dose or in 2-4 divided doses. In yet another embodiment, the dosage is from about 1 to about 50 mg/day, administered in a single dose or in 2-4 divided doses. In another embodiment, the dosage is from about 500 to about 1500 mg/day, administered in a single dose or in 2-4 divided doses. In still another embodiment, the dosage is from about 500 to about 1000 mg/day, administered in a single dose or in 2-4 divided doses. In yet another embodiment, the dosage is from about 100 to about 500 mg/day, administered in a single dose or in 2-4 divided doses.

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In a further embodiment, when the additional therapeutic agent is Ribavirin (commercially available as REBETOL ribavirin from Schering-Plough or COPEGUS ribavirin from Hoffmann-La Roche), this agent is administered at a daily dosage of from about 600 to about 1400 mg/day for at least 24 weeks.

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Compositions and Administration

Due to their activity, the 2'-Cyano Substituted Nucleoside Derivatives are useful in veterinary and human medicine. As described above, the 2'-Cyano Substituted Nucleoside Derivatives are useful for treating or preventing HCV infection in a patient in need thereof.

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When administered to a patient, the 2'-Cyano Substituted Nucleoside Derivatives can be administered as a component of a composition that comprises a pharmaceutically acceptable carrier or vehicle. The present invention provides pharmaceutical compositions comprising an effective amount of at least one 2'-Cyano Substituted Nucleoside Derivative and a pharmaceutically acceptable carrier. In the pharmaceutical compositions and methods of the present invention, the active ingredients will typically be administered in admixture with suitable carrier materials suitably selected with respect to the intended form of administration, i.e., oral tablets, capsules (either solid-filled, semi-solid filled or liquid filled), powders for constitution, oral gels, elixirs, dispersible granules, syrups, suspensions, and the like, and consistent with conventional pharmaceutical practices. For example, for oral administration in the form of tablets or capsules, the active drug component may be combined with any oral non-toxic pharmaceutically acceptable inert carrier, such as lactose, starch, sucrose, cellulose, magnesium stearate, dicalcium phosphate, calcium sulfate, talc, mannitol, ethyl alcohol (liquid forms) and the like. Solid form preparations include powders, tablets, dispersible granules, capsules, cachets and suppositories. Powders and tablets may be comprised of from about 0.5 to about 95 percent inventive composition. Tablets, powders, cachets and capsules can be used as solid dosage forms suitable for oral administration.

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Moreover, when desired or needed, suitable binders, lubricants, disintegrating agents and coloring agents may also be incorporated in the mixture. Suitable binders include starch, gelatin, natural sugars, corn sweeteners, natural and synthetic

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gums such as *acacia*, sodium alginate, carboxymethylcellulose, polyethylene glycol and waxes. Among the lubricants there may be mentioned for use in these dosage forms, boric acid, sodium benzoate, sodium acetate, sodium chloride, and the like. Disintegrants include starch, methylcellulose, guar gum, and the like. Sweetening and flavoring agents and preservatives may also be included where appropriate.

Liquid form preparations include solutions, suspensions and emulsions and may include water or water-propylene glycol solutions for parenteral injection.

Liquid form preparations may also include solutions for intranasal administration.

Also included are solid form preparations which are intended to be converted, shortly before use, to liquid form preparations for either oral or parenteral administration. Such liquid forms include solutions, suspensions and emulsions.

For preparing suppositories, a low melting wax such as a mixture of fatty acid glycerides or cocoa butter is first melted, and the active ingredient is dispersed homogeneously therein as by stirring. The molten homogeneous mixture is then poured into convenient sized molds, allowed to cool and thereby solidify.

Additionally, the compositions of the present invention may be formulated in sustained release form to provide the rate controlled release of any one or more of the components or active ingredients to optimize therapeutic effects, i.e., antiviral activity and the like. Suitable dosage forms for sustained release include layered tablets containing layers of varying disintegration rates or controlled release polymeric matrices impregnated with the active components and shaped in tablet form or capsules containing such impregnated or encapsulated porous polymeric matrices.

In one embodiment, the one or more 2'-Cyano Substituted Nucleoside Derivatives are administered orally.

In another embodiment, the one or more 2'-Cyano Substituted Nucleoside Derivatives are administered intravenously.

In one embodiment, a pharmaceutical preparation comprising at least one 2'-Cyano Substituted Nucleoside Derivative is in unit dosage form. In such form, the preparation is subdivided into unit doses containing effective amounts of the active components.

Compositions can be prepared according to conventional mixing, granulating or coating methods, respectively, and the present compositions can contain, in one embodiment, from about 0.1% to about 99% of the 2'-Cyano Substituted Nucleoside Derivative(s) by weight or volume. In various embodiments, the present compositions can contain, in one embodiment, from about 1% to about 70% or from about 5% to about 60% of the 2'-Cyano Substituted Nucleoside Derivative(s) by weight or volume.

The quantity of 2'-Cyano Substituted Nucleoside Derivative in a unit dose of preparation may be varied or adjusted from about 1 mg to about 2500 mg. In various embodiment, the quantity is from about 10 mg to about 1000 mg, 1 mg to about 500 mg, 1 mg to about 100 mg, and 1 mg to about 100 mg.

For convenience, the total daily dosage may be divided and administered in portions during the day if desired. In one embodiment, the daily dosage is administered in one portion. In another embodiment, the total daily dosage is administered in two divided doses over a 24 hour period. In another embodiment, the total daily dosage is administered in three divided doses over a 24 hour period. In still another embodiment, the total daily dosage is administered in four divided doses over a 24 hour period.

The amount and frequency of administration of the 2'-Cyano Substituted Nucleoside Derivatives will be regulated

52

according to the judgment of the attending clinician considering such factors as age, condition and size of the patient as well as severity of the symptoms being treated. Generally, a total daily dosage of the 2'-Cyano Substituted Nucleoside Derivatives range from about 0.1 to about 2000 mg per day, although variations will necessarily occur depending on the target of therapy, the patient and the route of administration. In one embodiment, the dosage is from about 1 to about 200 mg/day, administered in a single dose or in 2-4 divided doses. In another embodiment, the dosage is from about 10 to about 2000 mg/day, administered in a single dose or in 2-4 divided doses. In another embodiment, the dosage is from about 100 to about 2000 mg/day, administered in a single dose or in 2-4 divided doses. In still another embodiment, the dosage is from about 500 to about 2000 mg/day, administered in a single dose or in 2-4 divided doses.

The compositions of the invention can further comprise one or more additional therapeutic agents, selected from those listed above herein. Accordingly, in one embodiment, the present invention provides compositions comprising: (i) at least one 2'-Cyano Substituted Nucleoside Derivative or a pharmaceutically acceptable salt thereof; (ii) one or more additional therapeutic agents that are not a 2'-Cyano Substituted Nucleoside Derivative; and (iii) a pharmaceutically acceptable carrier, wherein the amounts in the composition are together effective to treat HCV infection.

In one embodiment, the present invention provides compositions comprising a Compound of Formula (I) and a pharmaceutically acceptable carrier.

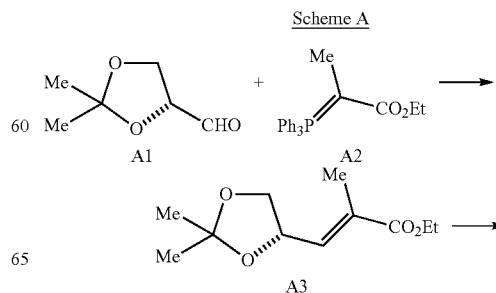
In another embodiment, the present invention provides compositions comprising a Compound of Formula (I), a pharmaceutically acceptable carrier, and a second therapeutic agent selected from the group consisting of HCV antiviral agents, immunomodulators, and anti-infective agents.

In another embodiment, the present invention provides compositions comprising a Compound of Formula (I), a pharmaceutically acceptable carrier, and to additional therapeutic agents, each of which are independently selected from the group consisting of HCV antiviral agents, immunomodulators, and anti-infective agents.

Methods for Making the Compounds of Formula (I):

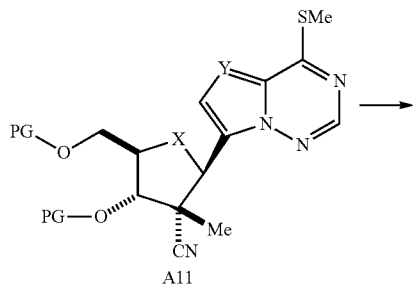
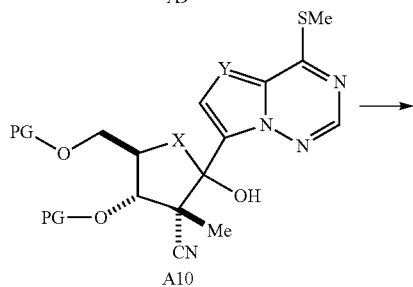
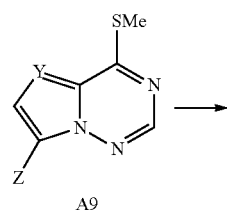
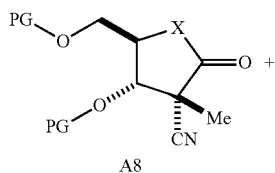
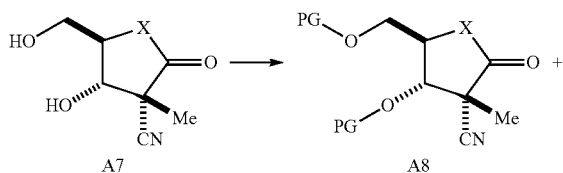
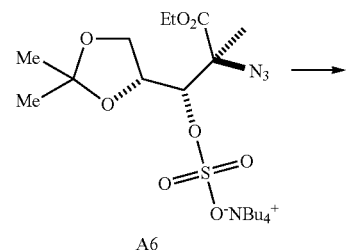
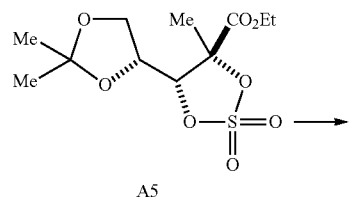
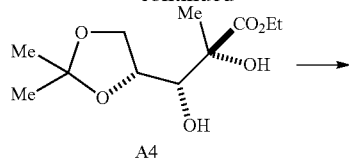
The Compounds of Formula (I) may be prepared from known or readily prepared starting materials, following methods known to one skilled in the art of organic synthesis. Methods useful for making the Compounds of Formula (I) are set forth in the Examples below and generalized in Schemes A-E below. Alternative synthetic pathways and analogous structures will be apparent to those skilled in the art of organic synthesis.

Scheme A shows a method useful for making nucleoside compounds of formula A12, which correspond to the Compounds of Formula (I), wherein R^1 is H, R^2 is H, R^3 is CH_3 , R^5 is H, and R^{18} is H.

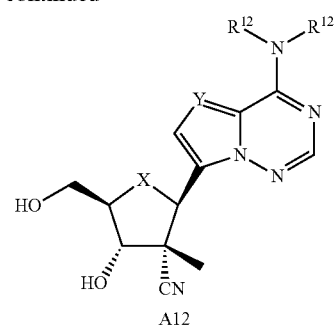


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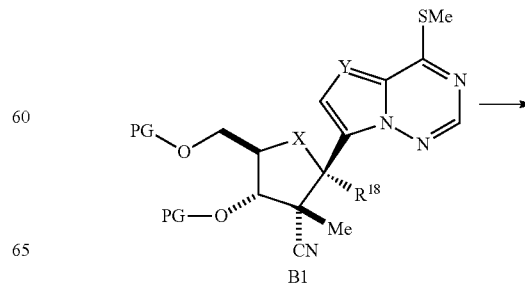
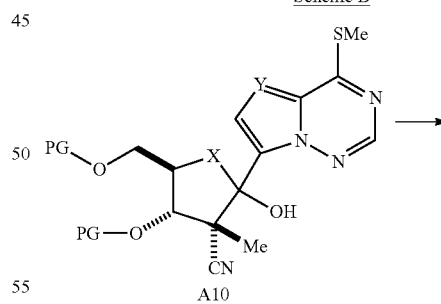


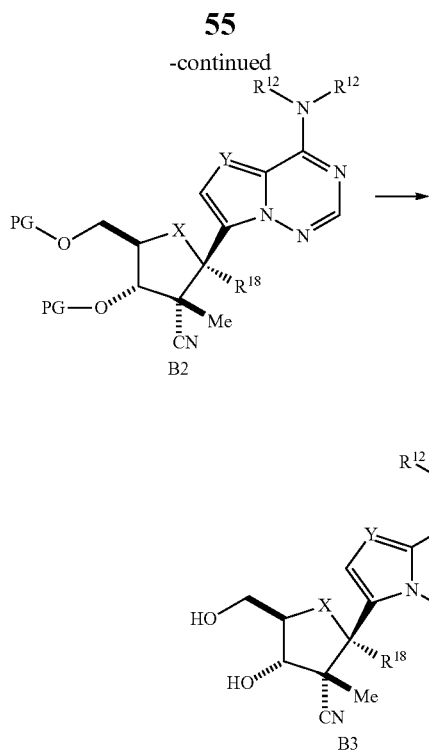
wherein X is O, CH₂, N, or S; Z is H or Br; PG is a hydroxyl protecting group; and Y and R¹² are as defined above for the Compounds of Formula (I).

Compound A1 can be reacted with compound A2 to provide compound A3, which can then be dihydroxylated using an appropriate reagent to provide compound A4. Sulfonylation of the hydroxyl groups of A4 using sulfonyl chloride provides compound A5. The cyclic sulfate of A5 can be opened using an azide source to provide compound A6. Compound A6 can then be converted to compound A7 under acidic conditions. The diol moiety of A7 can be protected with a variety of protecting groups to provide a compound of formula A8. Treatment of a compound of formula A9 with n-BuLi (if Z=Br) or LDA (if Z=H) followed by the addition of A8 provides access to compounds of formula A10. The 1'-hydroxy group of A10 can subsequently be removed to provide a compound of formula A11, which can then be treated with amines of formula —NH(R¹²)₂, followed by global deprotection of the hydroxyl groups to provide nucleoside compounds of formula A12.

Scheme B shows a method useful for making nucleoside compounds of formula B3, which correspond to the Compounds of Formula (I), wherein R¹ is H, R² is H, R³ is CH₃, and R⁵ is H.

Scheme B

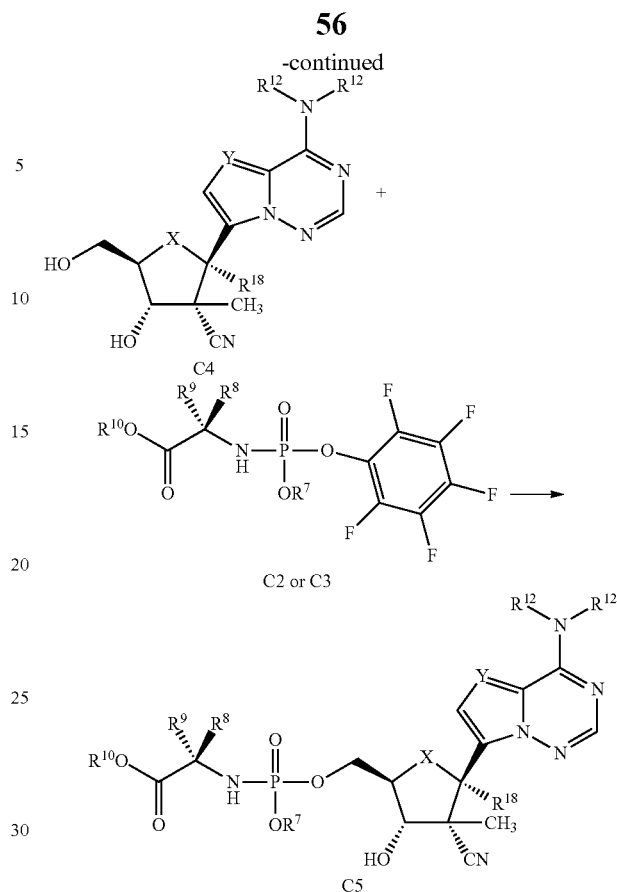




wherein X is O, CH₂, N, or S; and Y, R¹⁸, and R¹² are as defined above for the Compounds of Formula (I).

Compounds of formula A10 can be treated under Lewis acidic conditions in the presence of compounds such as TMS-R¹⁸ to provide compounds of formula B1. Compounds of formula B1 can then be treated with amines of formula —NH(R¹²)₂ to provide compounds of formula B2. Global deprotection of B2 provides nucleoside compounds of formula B3.

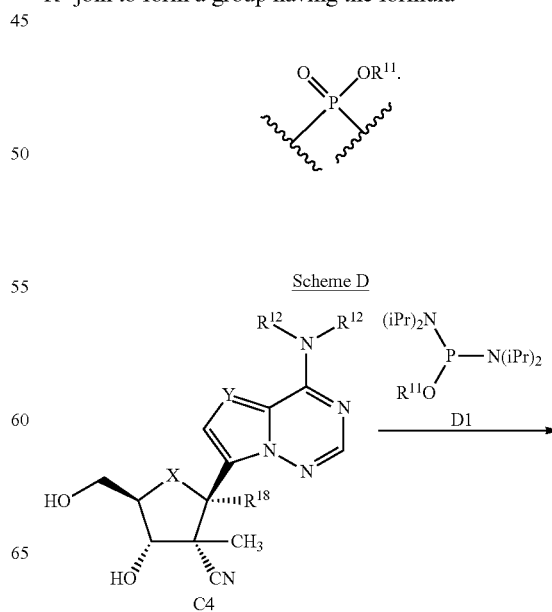
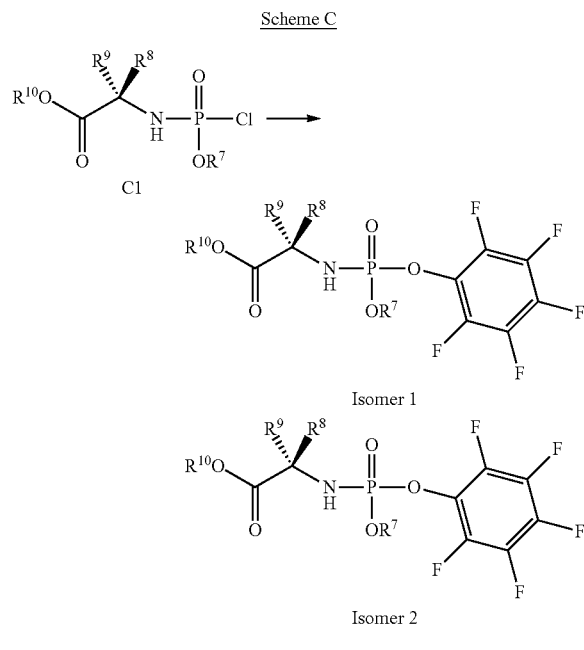
Scheme C shows a method useful for making nucleoside compounds of formula C5, which correspond to the Compounds of Formula (I), wherein R² is H, R³ is CH₃, R⁵ is H



wherein X is O, S, CH₂ or N; and Y, R⁷, R⁸, R⁹, R¹⁰, R¹² and R¹⁸ are as defined above for the Compounds of Formula (I).

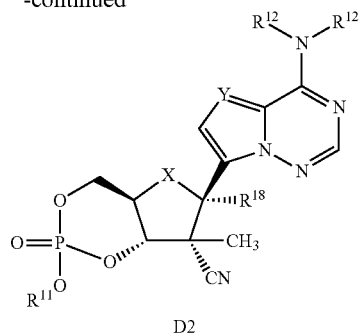
A compound of formula C1 can be reacted with pentafluorophenol to provide the isomeric compounds of formulas C2 and C3. These isomers can be individually reacted with a compound of formula C4 to produce compounds of formula C5.

Scheme D shows a method useful for making nucleoside compounds of formula D2, which correspond to the Compounds of Formula (I), wherein R³ is CH₃, R⁵ is H, and R¹ and R² join to form a group having the formula



57

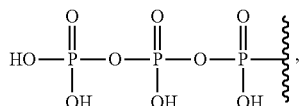
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wherein X is O, N, S, or CH₂ and R¹⁸, R¹¹, and R¹² are as defined above for the Compounds of Formula (I).

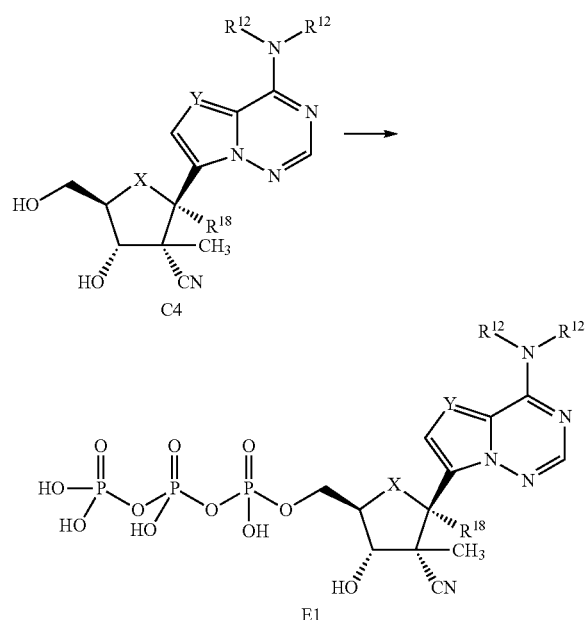
A compound of formula C4 can be reacted with a phosphoramidate compound of formula D1 followed by oxidation with, for example, m-chloroperbenzoic acid to provide a cyclic phosphate ester of formula D2.

Scheme E shows a method useful for making nucleoside compounds of formula E1, which correspond to the Compounds of Formula (I), wherein R1 is



R² is H, R³ is CH₃, R⁵ is H

Scheme E



wherein X is O, CH₂, N, or S and R¹⁸, R¹², and Y are as defined above for the Compounds of Formula (I).

Nucleoside compounds of formula C4 can be converted to their triphosphate analogs of formula E1 by treatment with phosphorus oxychloride followed by pyrophosphate.

58

Compounds of formula A12, B3, C5, D2, and E1 may be further elaborated using methods that would be well-known to those skilled in the art of organic synthesis or, for example, the methods described in the Examples below, to make the full scope of the Compounds of Formula (I).

One skilled in the art of organic synthesis will recognize that the synthesis of compounds with multiple reactive functional groups, such as —OH and NH₂, may require protection of certain functional groups (i.e., derivatization for the purpose of chemical compatibility with a particular reaction condition). Suitable protecting groups for the various functional groups of these compounds and methods for their installation and removal are well known in the art of organic chemistry. A summary of many of these methods can be found in Greene et al., *supra*.

One skilled in the art of organic synthesis will also recognize that one route for the synthesis of the Compounds of Formula (I) may be more desirable depending on the choice of appendage substituents. Additionally, one skilled in the relevant art will recognize that in some cases the order of reactions may differ from that presented herein to avoid functional group incompatibilities and thus adjust the synthetic route accordingly.

The starting materials used and the intermediates prepared using the methods set forth in Schemes A-E may be isolated and purified if desired using conventional techniques, including but not limited to filtration, distillation, crystallization, chromatography and the like. Such materials can be characterized using conventional means, including physical constants and spectral data.

EXAMPLES

General Methods

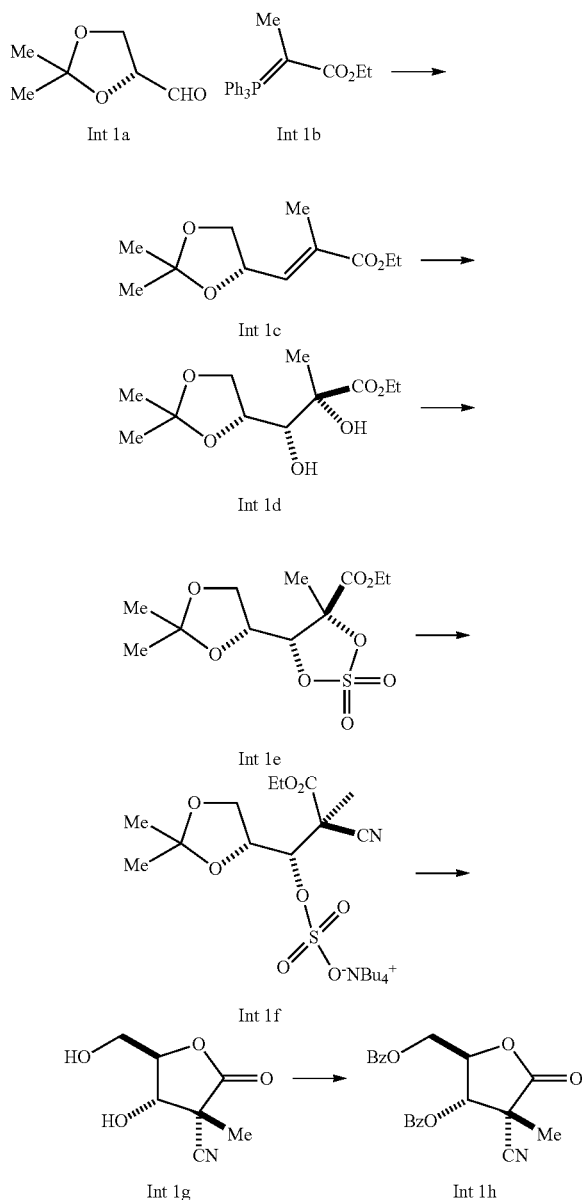
Solvents, reagents, and intermediates that are commercially available were used as received. Reagents and intermediates that are not commercially available were prepared in the manner as described below. ¹H NMR spectra were obtained on a Varian VNMR System 400 (400 MHz) and are reported as ppm downfield from Me₄Si with number of protons, multiplicities, and coupling constants in Hertz indicated parenthetically. Where LC/MS data are presented, analyses was performed using an Agilent 6110A MSD or an Applied Biosystems API-100 mass spectrometer and Shimadzu SCL-10A LC column: Altech platinum C18, 3 micron, 33 mm×7 mm ID; gradient flow: 0 minutes—10% CH₃CN, 5 minutes—95% CH₃CN, 5-7 minutes—95% CH₃CN, 7 minutes—stop. The parent ion is given. Flash chromatography on silica gel was performed using pre-packed normal phase silica from Isco, Biotage, Inc. or bulk silica from Fisher Scientific. Unless otherwise indicated, flash chromatography on silica gel was performed using a gradient elution of hexanes/ethyl acetate, from 100% hexanes to 100% ethyl acetate.

The Examples below provide illustrations of the conditions used for the preparation of the compounds of the present invention. These Examples are not intended to be limitations on the scope of the instant invention in any way, and they should not be so construed. Those skilled in the art of nucleoside and nucleotide synthesis will readily appreciate that known variations of the conditions and processes of the following preparative procedures can be used to prepare these and other compounds of the present invention. All temperatures are degrees Celsius unless otherwise noted.

59

Example 1

Preparation of Intermediate 1h



Step A: Synthesis of Intermediate Compound Int 1c

To a stirred solution of Int 1b (15.9 kg, 43.95 mol) in DCM (44.2 L) was added a solution of Int 1a (6.0 kg, 46.15 mol) in DCM (12 L) slowly with stirring at 0-5° C. over 1.5 hours. The resulting solution was stirred for 3 hours at 0-5° C. The resulting mixture was concentrated in vacuo. The residue was treated with petroleum-ether (50 L) to provide a precipitate. The solid was removed by vacuum filtration and the filtrate was distilled under reduced pressure (4 mm Hg). The fraction at 110-140° C. was collected to provide Int 1c as a light yellow liquid (8.2 kg, 82.5%).

Step B: Synthesis of Intermediate Compound Int 1d

To a stirred solution of Int 1c (4.2 kg, 19.63 mol), glycol (4.9 kg, 78.50 mol), NaHCO_3 (5.0 kg, 58.89 mol) and water

60

(8.4 L) in acetone (44.0 L) was added KMnO_4 (3.3 kg, 20.61 mol) in portions at -10° C. over 2 hours. The resulting solution was stirred for 1 hour at -10° C. in a liquid nitrogen bath. The reaction was then quenched by the addition of NaHSO_3 solution (6.0 L). The resulting solid was removed by filtration. The filtrate was diluted with H_2O (20 L) and extracted with ethyl acetate (4x3 L). The combined organic layers were dried over anhydrous Na_2SO_4 , filtered and concentrated in vacuo. The residue obtained was treated with hexanes (20 L) at -10° C. The resulting solid was collected by filtration and dried at 45° C. to provide Int 1d as a white solid (3.2 kg, 65.7%).

Step C: Synthesis of Intermediate Compound Int 1e

A stirred solution of Int 1d (6.2 kg, 25.00 mol) in dichloromethane (49.6 L) was treated with NEt_3 (7.6 kg, 75.00 mol). The resulting solution was treated with thionyl chloride (3.9 kg, 1.30 equivalents) dropwise with stirring at 25° C. over 3 hours. The resulting solution was stirred for 1 hour at 25° C. and then quenched by the addition of H_2O (15 L). The organic phase was washed with aqueous 10% NaHCO_3 (25 L) and then treated with aqueous NaOCl (124 L) and acetonitrile (6.2 L). The resulting mixture was stirred for an additional 48 hours at 15° C. and then quenched by the addition of aqueous Na_2SO_3 (45 L). The organic phase was washed with aqueous Na_2SO_3 (20 L) and brine (20 L). The organic phase was dried over anhydrous Na_2SO_4 , filtered and concentrated in vacuo to provide Int 1e as a light brown liquid (4.5 kg, 58.5%).

Step D: Synthesis of Intermediate Compound Int 1f

To a solution of Int 1e (4.5 kg, 14.52 mol) in acetone (27.0 L) and water (9.0 L) was added NaN_3 (943.6 g, 14.52 mol). The resulting solution was stirred for 16 hours at 50° C. and then the reaction was cooled and diluted with ethyl acetate (50 L). To the resulting mixture was treated with an aqueous solution of $\text{K}_2\text{HPO}_4 \cdot 3\text{H}_2\text{O}$ (5.1 kg in 45.0 L H_2O , 22.50 mol) and Bu_4NHSO_4 (5.2 kg, 15.25 mol). The resulting mixture was stirred for an additional 1 hour, and then extracted with ethyl acetate (20 L). The organic layer was dried over anhydrous Na_2SO_4 , filtered and concentrated in vacuo resulting in Int 1f as a light yellow solid that was used in the next step without purification. (5.0 kg).

Step E: Synthesis of Intermediate Compound Int 1g

To a 50 L reactor were charged Int 1f (5.0 kg, 8.42 mol), HCl (36%, 1.5 L), and ethanol (25.0 L). The resulting solution was stirred for 5 hours at 83° C. and then was concentrated in vacuo. The pH value of the residual solution was adjusted to 7 with aqueous NaHCO_3 (10%). The resulting solution was extracted with ethyl acetate (30 L). The organic layer was dried over anhydrous Na_2SO_4 , filtered and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/hexane (1:1-6:1) to provide Int 1g as a white solid (1.1 kg, 40% for 2 steps).

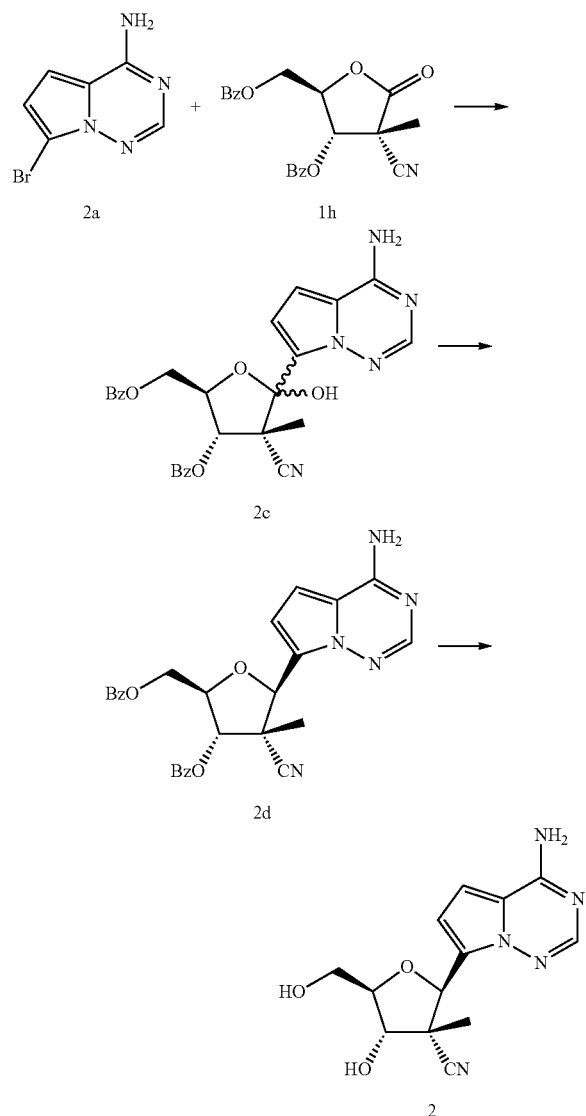
Step F: Synthesis of Intermediate Compound Int 1h

To a stirred solution of Int 1g (100 g, 534 mmol) in acetonitrile (500 mL) was added triethylamine (119 g, 1.17 mol) and DMAP (3.92 g, 32.1 mmol). The reaction was cooled to -10° C. and then treated with benzoyl chloride (136 mL, 1.17 mol) by additional funnel maintaining the reaction temperature below 20° C. After all starting material was consumed, the reaction was charged with water (3 L) and extracted with ethyl acetate (4x1 L). The combined organic layers were dried over Na_2SO_4 , filtered and concentrated in vacuo. The white solid obtained (Int 1h) was used in the next step without purification (122.5 g, 58%).

61

Example 2

Preparation of Compound 2



The synthesis of intermediate 2a is described in: Dixon et al., Preparation of substituted 4-amino-pyrrolo[2,3-b]pyridine derivatives useful for treating hyper-proliferative disorders and diseases associated with angiogenesis. WO 2007064931.

Step A—Synthesis of Compound 2c

Into a 250-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 2a (3.2 g, 15.02 mmol) in THF (40 mL). n-Butyllithium (18.75 mL, 1.6 N in THF) was added dropwise at -78°C ., and then chloro[2-(chlorodimethylsilyl)ethyl]dimethylsilane (3.2 g, 14.87 mmol) was added at -78°C .. After the resulting solution was stirred for 0.5 hours at -78°C ., n-butyllithium (6.25 mL, 1.6 N in THF) was added. After the resulting mixture was stirred for 5 minutes, a solution of compound 1h (3.7 g, 9.75 mmol) in THF (10 mL) was added to the mixture and the resulting solution was stirred for 2 hours at -78°C . After that the reaction was quenched by the

62

addition of 30 mL saturated aqueous solution of ammonium chloride, extracted with ethyl acetate ($3 \times 150\text{ mL}$), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:20~1:3) to provide 350 mg (7%) of compound 2c as an off-white solid. LC-MS: (ES, m/z): 514.0 $[\text{M}+\text{H}]^{+}$

Step B—Synthesis of Compound 2d

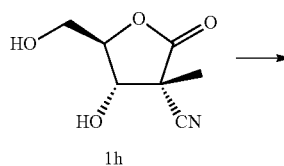
Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 2c (300 mg, 0.58 mmol) in DCM (10 mL). Et_3SiH (203 mg, 1.75 mmol) was added at room temperature and the resulting solution was stirred for 0.5 hours at room temperature. The resulting mixture was cooled down to 0°C ., then boron trifluoride etherate (248 mg, 1.75 mmol) was added to the mixture at 0°C . After the resulting solution was stirred for 2 hours at room temperature, the reaction was quenched by the addition of saturated aqueous solution of sodium bicarbonate. The resulting solution was extracted with dichloromethane ($3 \times 50\text{ mL}$), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (50:1~10:1) to give 100 mg (34%) of compound 2d as an off-white solid. LC-MS: (ES, m/z): 598.0 $[\text{M}+\text{H}]^{+}$, $^1\text{H-NMR}$: (400 MHz, CD_3OD , ppm): δ 8.14-8.16 (m, 2H), 8.04-8.05 (m, 2H), 7.83 (s, 1H), 7.41-7.66 (m, 6H), 6.89 (d, $J=2.2\text{ Hz}$, 1H), 6.73 (d, $J=2.2\text{ Hz}$, 1H), 6.11 (s, 1H), 5.49-5.52 (m, 1H), 4.83-4.84 (m, 1H), 4.70-4.74 (m, 1H), 4.09-4.11 (m, 1H), 1.33 (s, 3H).

Step C—Synthesis of Compound 2

Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 2d (100 mg, 0.20 mmol) in methanol (5 mL), NaOMe (20 mg, 0.37 mmol, 2.00 equiv). After the resulting solution was stirred for 2 hours at room temperature, the pH value of the solution was adjusted to 7 with hydrogen chloride. The resulting mixture was concentrated in vacuo. The crude product (60 mg) was purified by Prep-HPLC with the following conditions (1#-Pre-HPLC-001 (SHIMADZU Corp., Kyoto Japan)): Column, SunFire Prep C18 OBD Column, 5 μm , $19 \times 150\text{ mm}$, mobile phase, Water and CH_3CN (5.0% CH_3CN up to 19.0% in 9 min, up to 100.0% in 1 min, down to 5.0% in 2 min); Detector, UV 254 & 220 nm. This resulted in 35 mg (60%) of compound 2 as a white solid. LC-MS: (ES, m/z): 289.9 $[\text{M}+\text{H}]^{+}$, $^1\text{H-NMR}$: (400 MHz, CD_3OD , ppm): δ 7.83 (s, 1H), 6.90 (d, $J=2.2\text{ Hz}$, 1H), 6.85 (d, $J=2.2\text{ Hz}$, 1H), 5.98 (s, 1H), 4.05 (d, $J=3.4\text{ Hz}$, 1H), 3.93-3.96 (m, 2H), 3.77-3.82 (m, 1H), 1.12 (s, 3H).

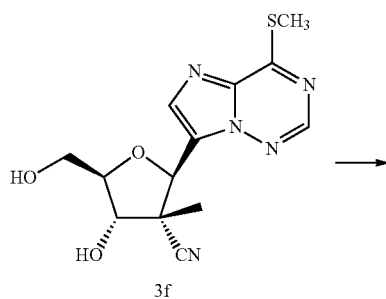
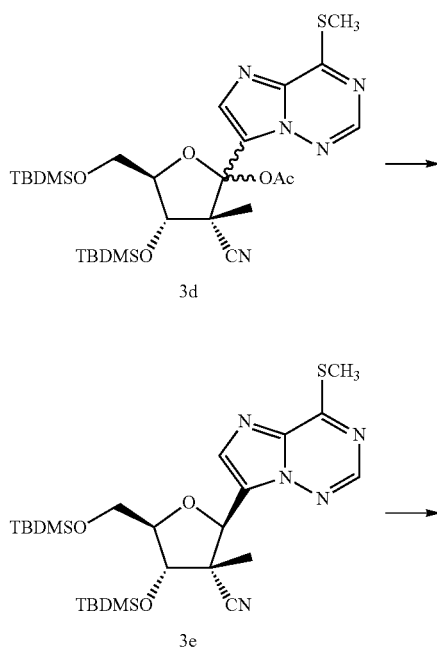
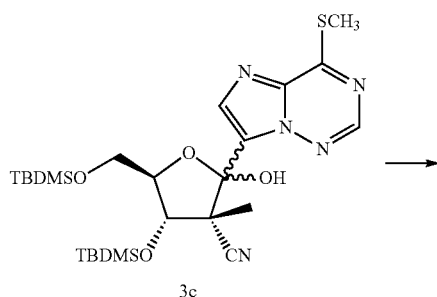
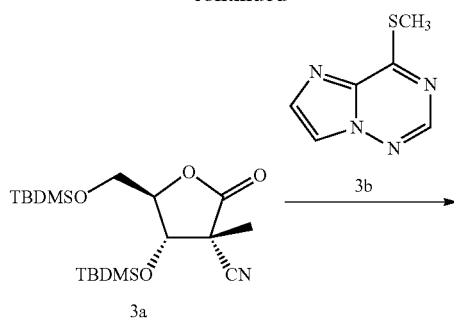
Example 3

Preparation of Compound 3

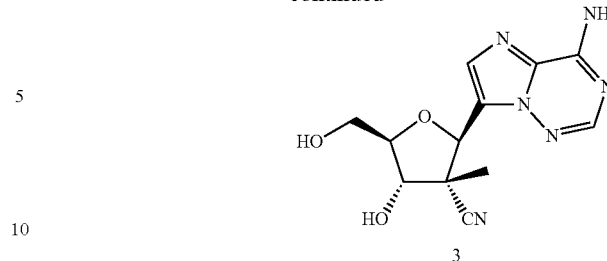


63

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The synthesis of compound 3b is reported by Dudfield et al. Journal of the Chemical Society, Perkin Transactions 1: Organic and Bio-Organic Chemistry (1972-1999), 1999, #20, 2929-2936.

Step A—Synthesis of Compound 3a

Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 1h (1.2 g, 7.01 mmol), TBDMSCl (5.28 g, 5.00 equivalents), and imidazole (2.86 g, 6.00 equivalents) in DMF (4 mL). After the resulting solution was stirred overnight at 50° C. in an oil bath, the reaction was concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 2.2 g (79%) of compound 3a as a white solid. LC-MS: (ES, m/z): 400.1 [M+H]⁺, ¹H-NMR (300 MHz, CDCl₃, ppm): δ 4.34 (m, 2H), 4.03 (dd, J=12.3, 1.5 Hz, 1H), 3.81 (dd, J=12.6, 1.8 Hz, 1H), 1.66 (s, 3H), 0.89-0.96 (m, 18H), 0.15-0.23 (m, 12H).

Step B—Synthesis of Compound 3c

Into a 50-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3b (285 mg, 1.71 mmol) in THF (5 mL). This was followed by the addition of LDA (0.94 mL, 1.10 equivalents) dropwise with stirring at -78° C. The resulting solution was stirred for 5 minutes at -78° C., and then a solution of compound 3a (755 mg, 1.89 mmol) in THF (3 mL) was added dropwise with stirring at -78° C. After the resulting solution was stirred for 40 minutes from -78 to -20° C., it was quenched by the addition of aqueous NH₄Cl at -40° C. The resulting solution was extracted with ethyl acetate (3×40 mL), washed with brine, dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:3) to give 460 mg (47%) of compound 3c as light yellow oil. LC-MS: (ES, m/z): 566.35 [M+H]⁺, ¹H-NMR (mixture of two isomer): (300 MHz, CDCl₃, ppm): δ 8.53 (s, 0.5H), 8.47 (s, 1H), 7.96 (s, 1H), 7.77 (s, 0.5), 4.81 (br s, 1H), 4.50 (d, J=9.6 Hz, 1H), 4.30 (m, 2H), 3.90 (m, 2H), 3.74 (m, 1.5H), 2.68 (d, 4.6H), 1.67 (s, 3H), 0.90 (m, 30H), 0.12 (m, 20H).

Step C—Synthesis of Compound 3d

Into a 50-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3c (500 mg, 0.88 mmol), 4-dimethylaminopyridine (20 mg, 0.16 mmol), and acetyl acetate (451 mg, 4.42 mmol) in pyridine (5 mL). The resulting solution was stirred for 30 minutes at 50° C. in an oil bath, and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:9) to give 450 mg (84%) of compound 3d acetate as a white powder. LC-MS: (ES, m/z): 608.2[M+H]⁺

65

Step D—Synthesis of Compound 3e

Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3d (350 mg, 0.58 mmol) and triethylsilane (0.28 mL, 3.00 equivalents) in DCM (3 mL). This was followed by the addition of $\text{BF}_3 \cdot \text{Et}_2\text{O}$ (0.11 mL, 1.50 equivalents) dropwise with stirring at 0° C. After the resulting solution was stirred for 1.5 hours at 0° C., the reaction was quenched by the addition of 0.5 mL of Et_3N and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:9) to give 250 mg (79%) of compound 3e as a white powder. LC-MS: (ES, m/z): 550.5 $[\text{M}+\text{H}]^+$, $^1\text{H-NMR}$: (300 MHz, CDCl_3 , ppm): δ 8.50 (s, 1H), 7.73 (s, 1H), 5.89 (s, 1H), 4.20 (d, J=6.0 Hz, 1H), 3.93 (m, 2H), 3.80 (dd, J=6.9, 2.7 Hz, 1H), 2.68 (s, 3H), 1.15 (s, 3H), 0.90 (d, 18H), 0.11 (m, 9H).

Step E—Synthesis of Compound 3f

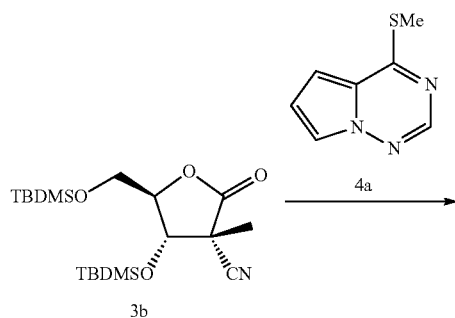
Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3e (80 mg, 0.15 mmol) in THF (1.5 mL). This was followed by the addition of a solution of TBAF (96 mg, 0.37 mmol) in THF (1 mL) dropwise with stirring at room temperature. The resulting solution was stirred for 1 hour at room temperature then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane:methanol (85:15) to give 36 mg (77%) of compound 3f as a white solid. LC-MS: (ES, m/z): 322.25 $[\text{M}+\text{H}]^+$, $^1\text{H-NMR}$: (300 MHz, CD_3OD , ppm): δ 8.59 (s, 1H), 7.89 (s, 1H), 5.89 (s, 1H), 4.09 (d, J=6.6 Hz, 1H), 3.91 (m, 2H), 3.75 (dd, J=4.5, 1.2 Hz, 1H), 2.70 (s, 3H), 1.14 (s, 3H).

Step F—Synthesis of Compound 3

Into a 10-mL sealed tube, was placed a solution of compound 3f (70 mg, 0.14 mmol) in $\text{NH}_3(\text{L})/\text{i-PrOH}$ (8 mL). The resulting solution was stirred for overnight at 50° C. in an oil bath, then was concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (10:1) to give 10 mg (25%) of compound 3 as a white solid. LC-MS: (ES, m/z): 291.15 $[\text{M}+\text{H}]^+$, $^1\text{H-NMR}$: (400 MHz, CD_3OD , ppm): δ 8.11 (s, 1H), 7.76 (s, 1H), 5.88 (s, 1H), 4.12 (d, J=6.4 Hz, 1H), 3.95 (m, 2H), 3.80 (m, 1H), 1.20 (s, 3H).

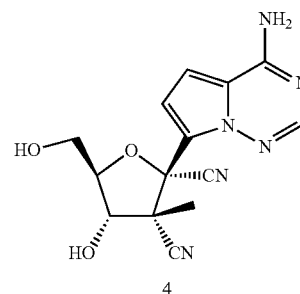
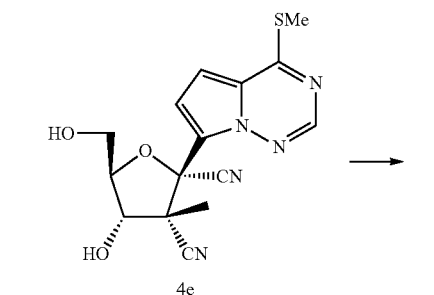
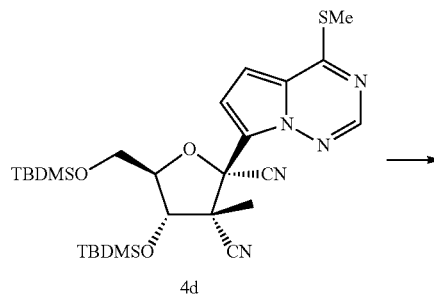
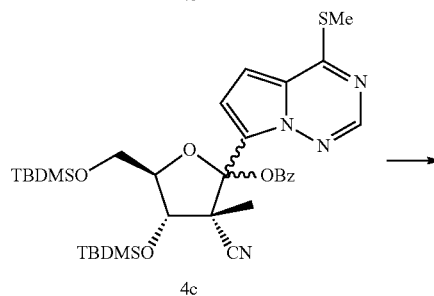
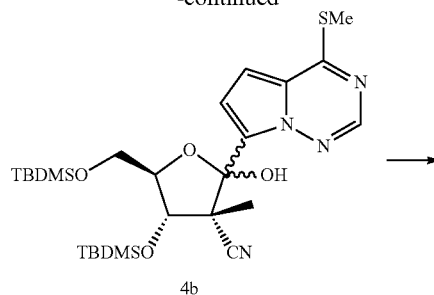
Example 4

Preparation of Compound 4



66

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Synthesis of Intermediate 4a:

The synthesis of 4-chloropyrrolo[2,1-f][1,2,4]triazine can be found in Babu et al., WO2011/150356A1, 2011.

Into a 500-mL round-bottom flask, was placed a solution of 4-chloropyrrolo[2,1-f][1,2,4]triazine (17 g, 110.70 mmol) and (methylsulfanyl)sodium (15 g, 214.01 mmol) in tetrahydrofuran (300 mL). The resulting solution was stirred overnight at room temperature. The solids were filtered out. The resulting mixture was concentrated in vacuo. The residue was

67

applied onto a silica gel column with ethyl acetate/petroleum ether (1:10). This resulted in 9 g (49%) of compound 4a as a yellow solid. LC-MS (ES, m/z): 166 [M+H]⁺

Step A—Synthesis of Compound 4b

Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of 4a (1.7 g, 10.29 mmol) in THF (50 mL). LDA (8 mL, 1.6 N in THF) was added to the mixture at -78° C. The resulting solution was stirred for 20 minutes at -78° C., and then treated dropwise with compound 3b (5 g, 12.51 mmol) in THF (10 mL) at -78° C. The resulting solution was stirred for 1 hour at -78° C. and then quenched by the addition of NH₄Cl, extracted with ethyl acetate (3×100 mL), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 5 g (86%) of compound 4b as yellow oil. LC-MS: (ES, m/z): 565.0 [M+H]⁺, 587.2 [M+Na]⁺

Step B—Synthesis of Compound 4c

Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of 4b (3.2 g, 5.66 mmol), 4-dimethylaminopyridine (1.39 g, 11.38 mmol) and triethylamine (1.72 g, 17.00 mmol) in DCM (20 mL). Benzoyl chloride (950 mg, 6.76 mmol) was added to the mixture at 0° C. After the resulting solution was stirred for 2 hours at room temperature, the reaction was quenched by the addition of 5 mL of water/ice. The resulting solution was extracted with ethyl acetate (3×100 mL), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 3.7 g (98%) of compound 4c as a yellow solid. LC-MS: (ES, m/z): 692.0 [M+Na]⁺

Step C—Synthesis of Compound 4d

Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of 4c (1 g, 1.49 mmol) in DCM (10 mL) and trimethylsilylcyanide (0.6 mL, 3.00 equivalents). Boron trifluoride diethyl etherate (0.6 mL, 1.20 equivalents) was then added to the mixture at 0° C. After the resulting solution was stirred for 4 hours at room temperature, the reaction was quenched by the addition of 50 mL sodium bicarbonate. The resulting solution was extracted with ethyl acetate (3×50 mL), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 0.8 g (93%) of compound 4d as yellow oil. LC-MS: (ES, m/z): 574.0 [M+H]⁺, 615.0 [M+CH₃CN]⁺

Step D—Synthesis of Compound 4e

Into a 25-mL round-bottom flask, was placed compound 4d (30 mg, 0.05 mmol), tetrabutylammonium fluoride (27 mg, 0.82 mmol) in THF (3 mL). The resulting solution was stirred for 1 hour at room temperature, and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (10:1) to give 14 mg (78%) of compound 4e as yellow oil. LC-MS: (ES, m/z): 346.0 [M+H]⁺

Step E—Synthesis of Compound 4

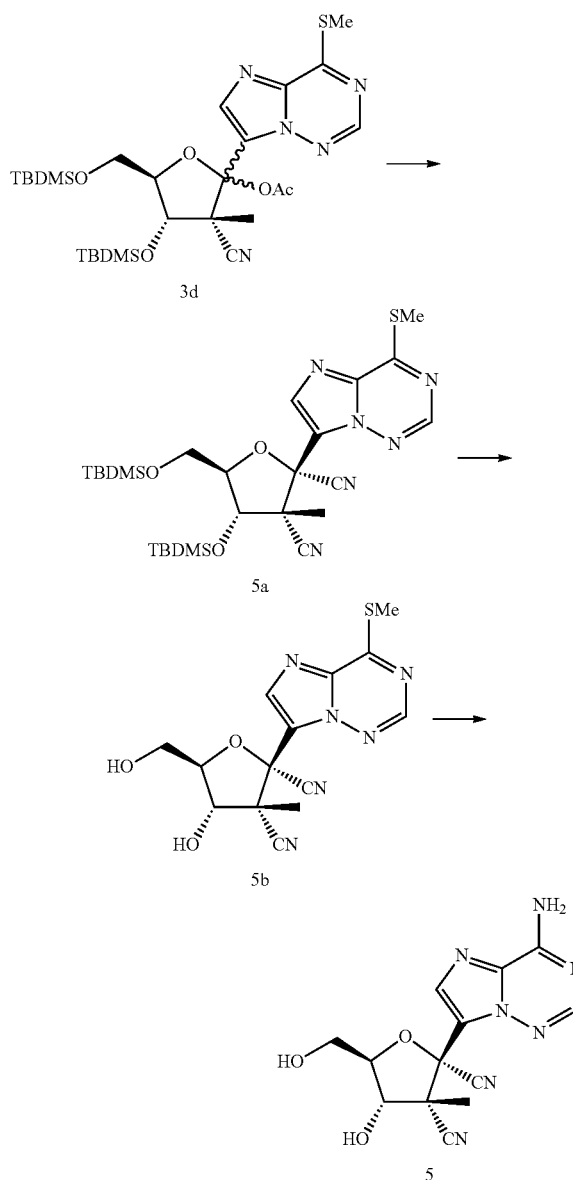
Into a 25-mL sealed tube, was placed compound 4e (400 mg, 1.16 mmol, 1.00 equiv), liquid ammonia (5 mL) and propan-2-ol (10 mL). The resulting solution was stirred for 8 hours at 40° C. and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (10:1) to give 170 mg (47%) of compound 4 as off-white solid. LC-MS: (ES, m/z): 315.0 [M+H]⁺, 337 [M+Na]⁺, ¹H-NMR: (CD₃OD, 300 MHz, ppm):

68

δ 7.94 (s, 1H), 6.97 (d, J=2.3 Hz, 1H), 6.93 (d, J=2.4 Hz, 1H), 4.23-4.28 (m, 1H), 4.12 (d, J=3.5 Hz, 1H), 3.81-4.04 (m, 2H), 1.05 (s, 3H).

Example 5

Preparation of Compound 5



Step A—Synthesis of Compound 5a

Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3d (1.6 g, 2.63 mmol) in DCM (40 mL). Trimethylsilylcarbonitrile (1.41 mL, 4.00 equivalents) was added. This was followed by the addition of BF₃·OEt₂ (0.99 mL, 3.00 equivalents) dropwise with stirring at 0° C. After the resulting solution was stirred for 1 hour at 0° C. in an ice/salt bath, the reaction was quenched by the addition of 2 mL of triethylamine and 30 mL of NaHCO₃ (saturated aqueous). The resulting mixture was washed with saturated sodium bicar-

69

bonate (3×100 mL), brine, dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1/10) to give 1 g (66%) of compound 5a as a white solid. LC-MS: (ES, m/z): 575.3 [M+H]⁺

Step B—Synthesis of Compound 5b

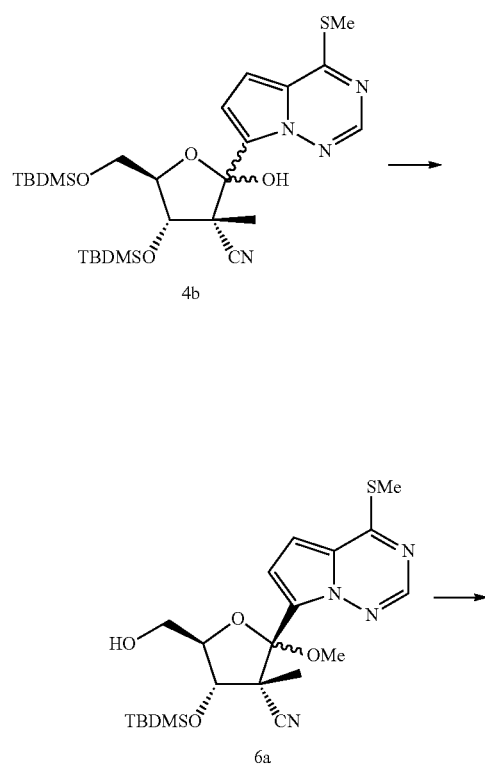
Into a 50-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 5a (500 mg, 0.87 mmol) in THF (20 mL). TBAF (550 mg, 1.74 mmol) was added. The resulting solution was stirred for 30 minutes at room temperature and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (12/1) to give 200 mg (66%) of compound 5b as a red solid. LC-MS: (ES, m/z): 346.95 [M+H]⁺

Step C—Synthesis of Compound 5

Into a 20-mL sealed tube, was placed a solution of compound 5b (300 mg, 0.87 mmol) in propan-2-ol (3 mL) and NH₃(l) (12 mL). The resulting solution was stirred for 6 hours at 40° C. in an oil bath and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (12/1) to give 200 mg (73%) of compound 5 as a white solid. LC-MS: (ES, m/z): 316.0 [M+H]⁺, ¹H-NMR: (400 MHz, CD₃OD, ppm): δ 8.20 (s, 1H), 7.86 (s, 1H), 4.27-4.31 (m, 1H), 4.19-4.20 (m, 1H), 4.01-4.05 (m, 1H), 3.83-3.87 (m, 1H), 1.16 (s, 3H).

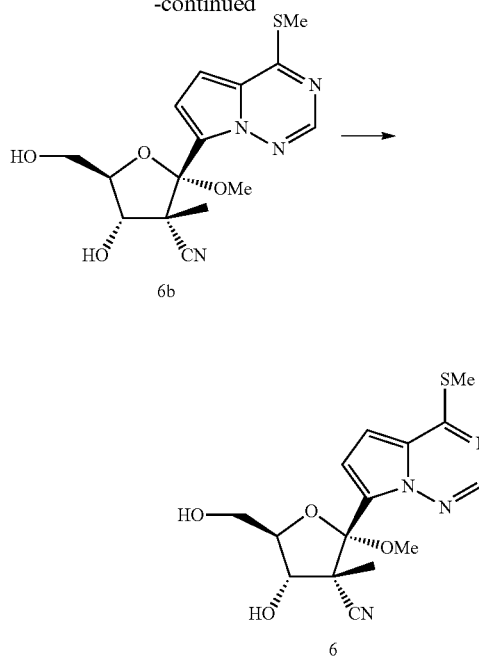
Example 6

Preparation of Compound 6



70

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Step A—Synthesis of Compound 6a

Into a 100-mL round-bottom flask, was placed compound 4b (2 g, 3.54 mmol) and sulfuric acid (0.5 mL) in methanol (50 mL). The resulting solution was stirred for overnight at room temperature and then concentrated in vacuo to give 1.7 g (103%) of compound 6a as yellow crude oil that was used without purification. LC-MS: (ES, m/z): 465.0 [M+H]⁺

Step B—Synthesis of Compound 6b

Into a 25-mL round-bottom flask, was placed a solution of compound 6a (80 mg, 0.17 mmol) and tetrabutylammonium fluoride (70 mg, 2.13 mmol) in THF (8 mL). The resulting solution was stirred for 2 hours at room temperature and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:1). The product was purified by Prep-HPLC with the following conditions (1#-Pre-HPLC-011(Waters)): Column, XBridge Shield RP18 OBD Column, 5 μm, 19×150 mm; mobile phase, water with 10 mmol NH₄HCO₃ and CH₃CN (5.0% CH₃CN up to 45.0% in 10 min, up to 95.0% in 2 min, down to 5.0% in 2 min); Detector, UV 254 & 220 nm. This resulted in 20 mg (33%) of compound 6b as a light yellow solid. LC-MS: (ES, m/z): 351.1 [M+H]⁺, ¹H-NMR: (CDCl₃, 300 MHz, ppm): δ 8.29 (s, 1H), 6.99 (d, J=2.3 Hz, 1H), 6.85 (d, J=2.3 Hz, 1H), 4.06-4.24 (m, 3H), 3.86-3.91 (m, 1H), 2.68 (s, 3H), 1.13 (s, 3H).

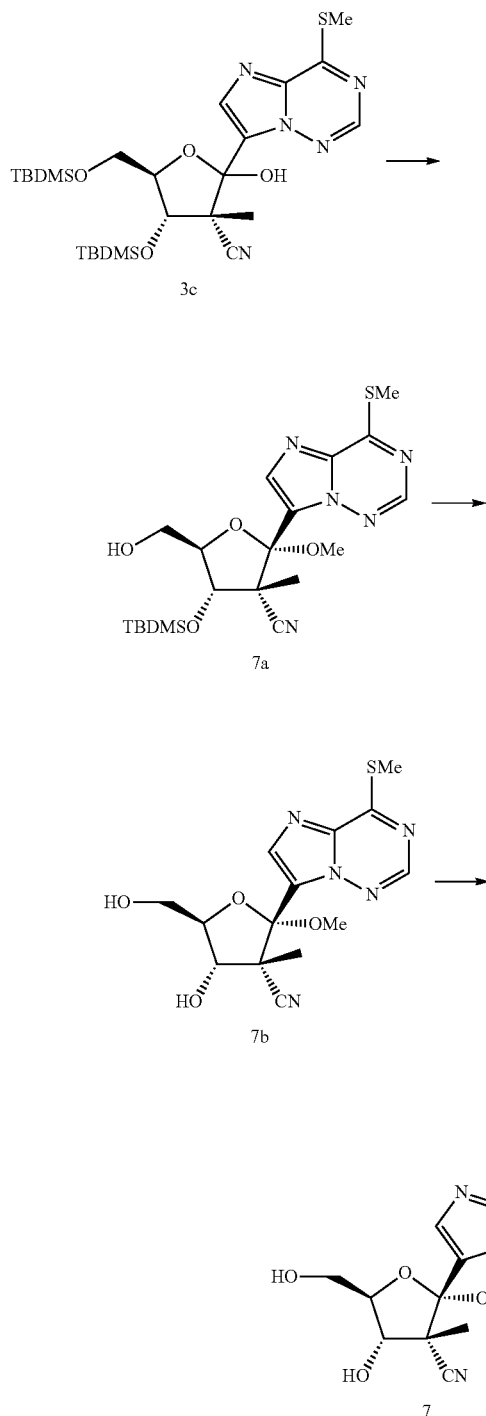
Step C—Synthesis of Compound 6

Into a 25-mL sealed tube, was placed compound 6b (350 mg, 1.00 mmol, 1.00 equiv) in liquid ammonia (6 mL) and propan-2-ol (12 mL). The resulting solution was stirred overnight at 50° C. The resulting mixture was concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (10:1) to give 140 mg (44%) of compound 6 as a white solid. LC-MS: (ES, m/z): 320.2 [M+H]⁺, ¹H-NMR: (CD₃OD, 400 MHz, ppm): δ 7.86 (s, 1H), 6.96 (d, J=2.2 Hz, 1H), 6.90 (d, J=2.2 Hz, 1H), 3.94-4.05 (m, 3H), 3.77-3.81 (m, 1H), 3.09 (s, 3H), 1.05 (s, 3H).

71

Example 7

Preparation of Compound 7



Step A—Synthesis of Compound 7a

Into a 50-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3c (200 mg, 0.35 mmol) in methanol (20 mL). This was followed by the addition of concentrated H_2SO_4 (0.0392 mL, 2.00 equivalents) dropwise with stirring at room

72

temperature. The resulting solution was stirred overnight at room temperature and then quenched by the addition of 1 mL of triethylamine. The resulting solution was extracted with ethyl acetate (3×100 mL), washed with brine (2×100 mL), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (20/1) to give 100 mg (61%) of compound 7a as a white solid. LC-MS: (ES, m/z): 466.5 $[\text{M}+\text{H}]^+$, $^1\text{H-NMR}$: (400 MHz, CD_3OD , ppm): δ 8.67 (s, 1H), 7.99 (s, 1H), 4.21-4.22 (d, $J=6.0$, 1H), 4.08-4.13 (m, 1H), 3.98-4.02 (m, 1H), 3.77-3.81 (m, 1H), 3.12 (s, 3H), 2.77 (s, 3H), 1.24 (s, 3H) 0.91-1.01 (m, 9H), 0.18-0.22 (m, 6H).

Step B—Synthesis of Compound 7b

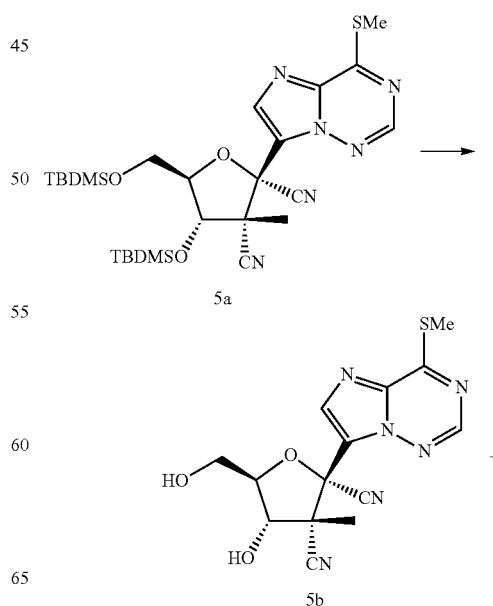
Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 7a (1 g, 2.15 mmol) and TBAF (677 mg, 2.15 mmol) in THF (30 mL). The resulting solution was stirred for 30 minutes at room temperature and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (12/1) to give 400 mg (53%) of compound 7b as a white solid. LC-MS: (ES, m/z): 352.1 $[\text{M}+\text{H}]^+$

Step C—Synthesis of Compound 7

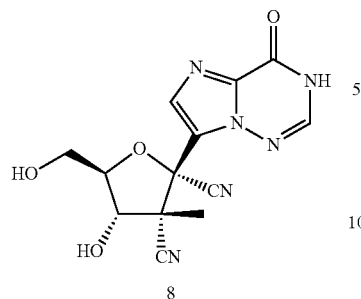
Into a 20-mL sealed tube, was placed a solution of compound 7b (400 mg, 1.14 mmol) in propan-2-ol (3 mL) and $\text{NH}_3(1)$ (12 mL). The resulting solution was stirred for 6 hours at 40° C. in an oil bath. The resulting mixture was concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (10/1) to give 200 mg (55%) of compound 7 as a white solid. LC-MS: (ES, m/z): 343.05 $[\text{M}+\text{Na}]^+$, $^1\text{H-NMR}$: (400 MHz, CD_3OD , ppm): δ 8.13 (s, 1H), 7.81 (s, 1H), 3.95-4.09 (m, 1H), 4.03-4.11 (m, 3H), 3.78-3.82 (m, 1H), 3.14 (s, 3H), 1.11 (s, 3H).

Example 8

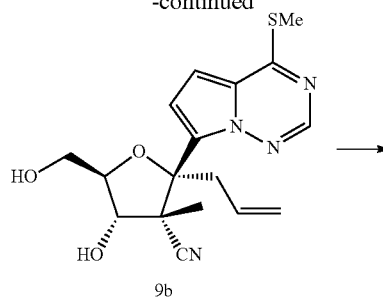
Preparation of Compound 8



73
-continued



74
-continued

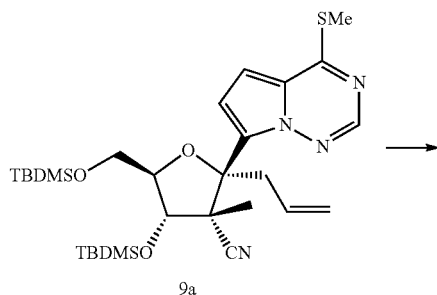
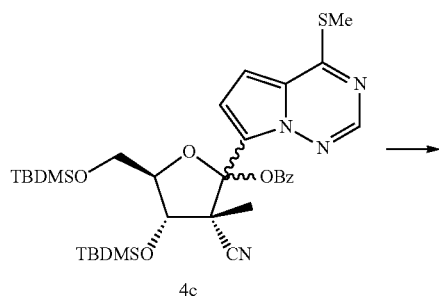


Step A—Synthesis of Compound 8

Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 5a (500 mg, 0.87 mmol) in tetrahydrofuran (30 mL), TBAF₃H₂O (137 mg, 0.43 mmol, 0.50 equiv). The resulting solution was stirred overnight at room temperature and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (9/1) to give 100 mg (36%) of compound 5b as a white solid and 100 mg (33%) of compound 8 as a red solid. LC-MS: (ES, m/z): 316.95 [M+H]⁺, ¹H-NMR: (300 MHz, CD₃OD, ppm): δ 8.22 (s, 1H), 7.66 (s, 1H), 6.68-6.69 (d, J=4.8, 1H), 5.20-5.24 (m, 1H), 4.03-4.11 (m, 2H), 3.81-3.87 (m, 1H), 3.62-3.70 (m, 1H), 1.09 (s, 3H).

Example 9

Preparation of Compound 9



Step A—Synthesis of Compound 9a

Into a 100-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 4c (4 g, 5.98 mmol), trimethyl(prop-2-en-1-yl) silane (4 mL), ethoxyethane; and trifluoroborane (2.5 mL) in DCM (40 mL). The resulting solution was stirred for 4 hours at -78° C. and then quenched by the addition of sodium bicarbonate. The resulting solution was extracted with ethyl acetate (3×100 mL), dried over anhydrous sodium sulfate and concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 1.5 g (43%) of compound 9a as yellow oil. LC-MS: (ES, m/z): 589.25 [M+H]⁺

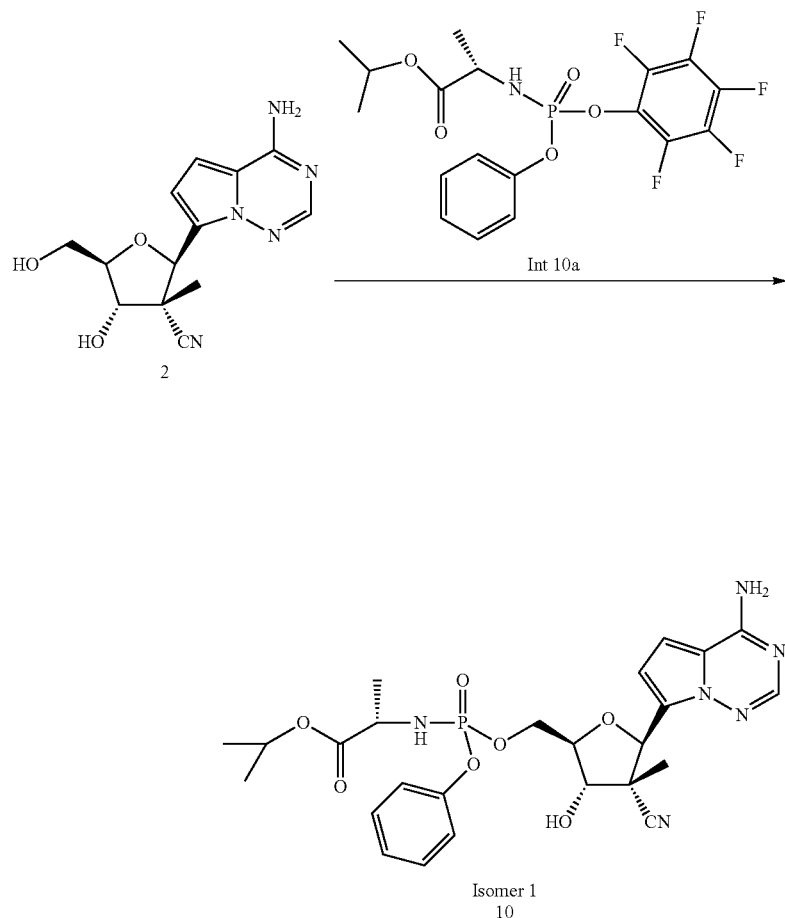
Step B—Synthesis of Compound 9b

Into a 25-mL round-bottom flask, was placed a solution of compound 9a (800 mg, 1.36 mmol) and TBAF (700 mg, 2.68 mmol) in THF (10 mL). The resulting solution was stirred for 2 minutes at room temperature and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:10) to give 350 mg (71%) of compound 9b as yellow oil. LC-MS: (ES, m/z): 361.05 [M+H]⁺

Step C—Synthesis of Compound 9

Into an 80-mL round-bottom flask, was placed compound 9b (500 mg, 1.39 mmol), NH₃ (40 mL), and i-propanol (20 mL). The resulting solution was stirred for 5 days at 50° C. and then concentrated in vacuo. The residue was applied onto a silica gel column and eluted with ethyl acetate/petroleum ether (1:1) to give 350 mg (77%) of compound 9 as a white solid. LC-MS: (ES, m/z): 330.10 [M+H]⁺, ¹H-NMR (MeOD, 400 MHz, ppm): δ 7.83 (s, 1H), 6.83-6.87 (m, 2H), 5.42-5.53 (m, 1H), 4.93 (d, J=10.8 Hz, 1H), 4.79 (d, J=5.2 Hz, 1H), 3.90-4.00 (m, 3H), 3.76-3.3.81 (m, 2H), 2.99-3.07 (m, 1H), 1.04 (s, 3H).

Preparation of Compound 10



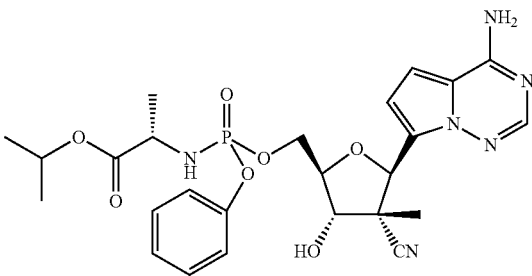
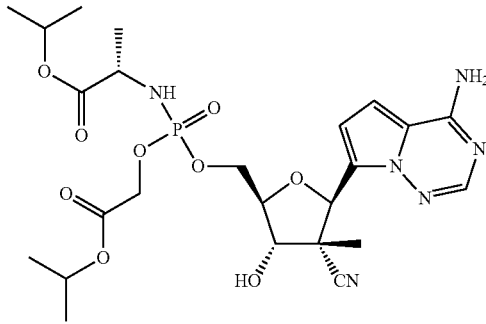
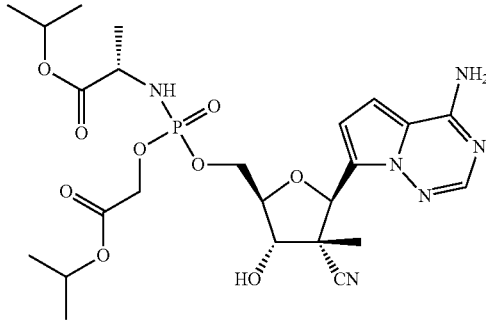
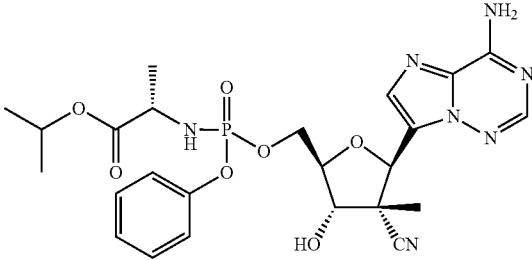
Phosphorylamino chloride reactants of type Int-10a can be made using the methods described in U.S. Pat. No. 7,879,815.

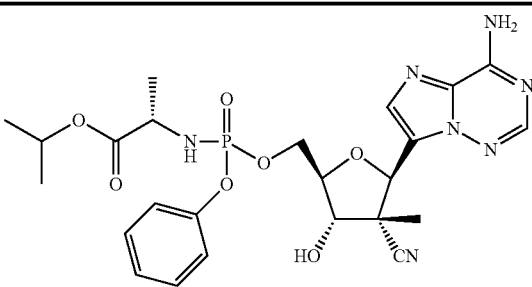
Step A—Synthesis of Compound 10

Into a 50-mL 3-necked round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 2 (60 mg, 0.21 mmol) in 4.5 mL THF. This was followed by the addition of lithio[(2,2,6,6-tetramethylpiperidin-1-yl)magnesium]-1,3-dichlorane (1M/L, 0.27 mmol, 1.30 equivalents) dropwise with stirring at 0° C. To this mixture was added a solution of Int-10a (single diastereomer, 0.27 mmol, 1.30 equivalents) in 0.5 mL THF dropwise with stirring at 0° C. The resulting solution was stirred overnight at room temperature, then the reaction was quenched by the addition of 5 mL of ammonium chloride aqueous at 0° C. and concentrated in vacuo. The resulting solution was extracted with ethyl acetate, dried over anhydrous Na₂SO₄ and concentrated under reduced pressure. The residue was applied onto a silica gel column and eluted with dichloromethane/methanol (25:1). The crude product was purified by Prep-HPLC with the following conditions (1#-Pre-HPLC-011(Waters)): Column, SunFire Prep C18 OBD Column, 5 μm, 19*150 mm, mobile phase, water with 10 mmol ammonium bicarbonate

and acetonitrile (20.0% acetonitrile up to 42.0% in 18 min, up to 95.0% in 2 min, down to 20.0% in 1 min); Detector, UV 254 & 220 nm and then the two isomers were separated by Chiral-Prep-HPLC with the following conditions (2#-Gilson Gx 281(HPLC-09)): Column, Chiralpak IC, 2*25 cm, Sum; mobile phase, heptane (0.1% diethylamine) and ethanol (0.2% diethylamine) (hold 20.0% ethanol (0.2% diethylamine) in 15 min); Detector, UV 254 & 220 nm. This resulted in 12.03 mg (10%) of compound 10 as a white solid by lyophilization. LC-MS: (ES, m/z): 559.1 [M+H]⁺, 581.2 [M+Na]⁺, ¹H-NMR: (300 MHz, CD₃OD, ppm): δ 7.55 (s, 1H), 7.23-7.28 (m, 2H), 7.11-7.17 (m, 3H) 6.77 (d, J=4.50 Hz, 1H), 6.64 (d, J=4.50 Hz, 1H), 5.89 (s, 1H), 4.92 (m, 1H), 4.39-4.45 (m, 1H), 4.28-4.30 (m, 1H), 3.94-3.99 (m, 2H), 3.85 (dd, J=7.20 Hz, J=9.00 Hz, 1H), 1.23 (dd, J=0.90 Hz, J=4.20 Hz, 3H), 1.13 (dd, J=2.40 Hz, J=6.30 Hz, 6H), 0.95 (s, 3H), P-NMR: (121 MHz, CD₃OD, ppm): δ 3.79 (s, 1P)

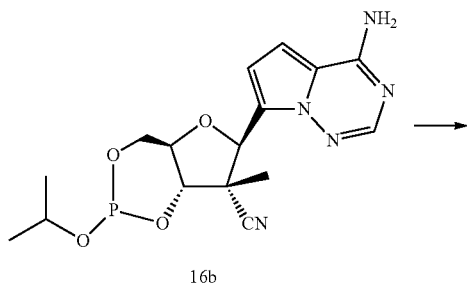
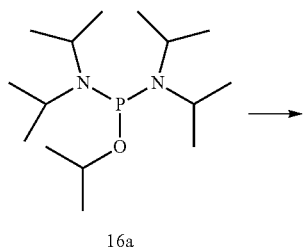
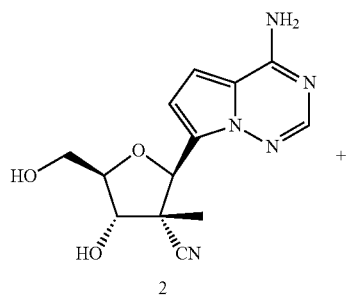
The following compounds of the present invention were made using the methods described in the Example above and substituting the appropriate reactants and/or reagents. Note that the designation of isomers is arbitrary and only suggests that the compound is a single isomer.

Compd #	Structure	Starting Material	LC-MS or MS(M + H)
11		Compound 2	559
Isomer 2			
12		Compound 2	583
Isomer 1			
13		Compound 2	583
Isomer 2			
14		Compound 3	560
Isomer 1			

Compd #	Structure	Starting Material	LC-MS or MS(M + H)
15		Compound 3	560
Isomer 2			

Example 11

Preparation of Compounds 16 and 17



20

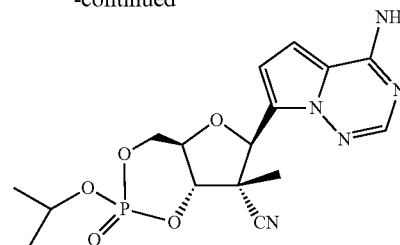
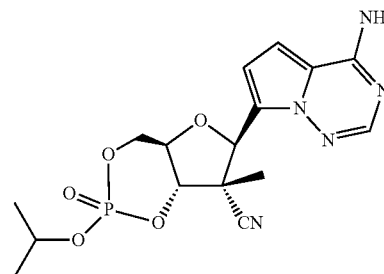
25

30

35

40

45

16
Isomer 117
Isomer 2

Step A—Synthesis of Compound 16b

Into a 250-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 2 (400 mg, 1.38 mmol) in acetonitrile (150 mL). This was followed by the addition of 1H-imidazole-4,5-dicarbonitrile (410 mg, 3.47 mmol). After the resulting mixture was allowed to react with stirring at room temperature for 30 minutes, a solution of intermediate 16a (520 mg, 1.79 mmol) in THF (2 mL) was added at 0° C. in 10 minutes. The resulting solution was stirred overnight at 0° C., and then the solids were collected by filtration and the resulting solution was concentrated in vacuo to give 650 mg (7%) of compound 16b as yellow oil.

Step B—Synthesis of Compounds 16 and 17

Into a 250-mL round-bottom flask, was placed a solution of compound 16b (650 mg, 0.10 mmol) in THF/pyridine/water (78:20:2) (70 mL). This was followed by the addition of iodide (~30 mg) in several batches at 0° C. in 20 minutes. The resulting solution was stirred for 30 minutes at 0° C. After the reaction was completed, the resulting mixture was concentrated in vacuo. The crude product (400 mg) was purified by

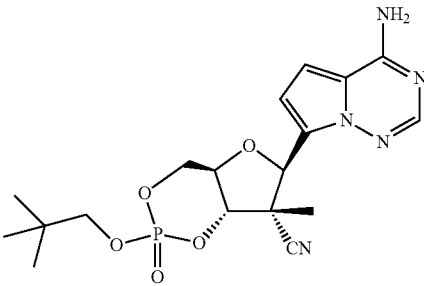
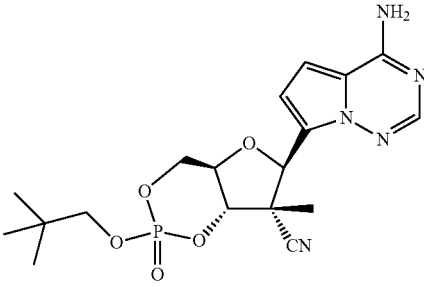
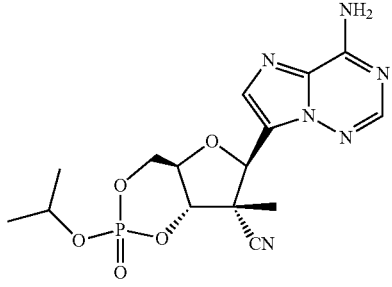
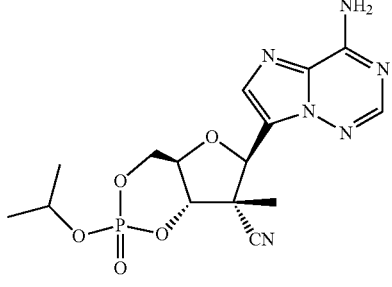
81

Prep-HPLC with the following conditions (1#-Pre-HPLC-011(Waters)): Column, SunFire Prep C18, 19*150 mm Sum; mobile phase, water and acetonitrile (20.0% acetonitrile up to 79.0% in 8 min, up to 100.0% in 1 min, down to 20.0% in 1 min); Detector, UV 254 & 220 nm. This resulted in 51.6 mg of compound 16 as a white solid, and 80.5 mg of compound 17 as a white solid. LCMS 16: 394.15 [M+H]⁺, ¹H-NMR: (300 MHz, CD₃OD, ppm): 7.85 (s, 1H), 6.92 (d, J=4.5 Hz,

82

1H), 6.77 (d, J=4.5 Hz, 1H), 6.15 (s, 1H), 4.69-4.90 (m, 3H), 4.5-4.62 (m, 1H), 4.28-4.34 (m, 1H), 1.31-1.48 (dd, J=13.6 Hz, J=6.0 Hz, 6H), 1.18 (s, 3H), P-NMR 16: (300 MHz, CD₃OD, ppm): -7.396 (s)

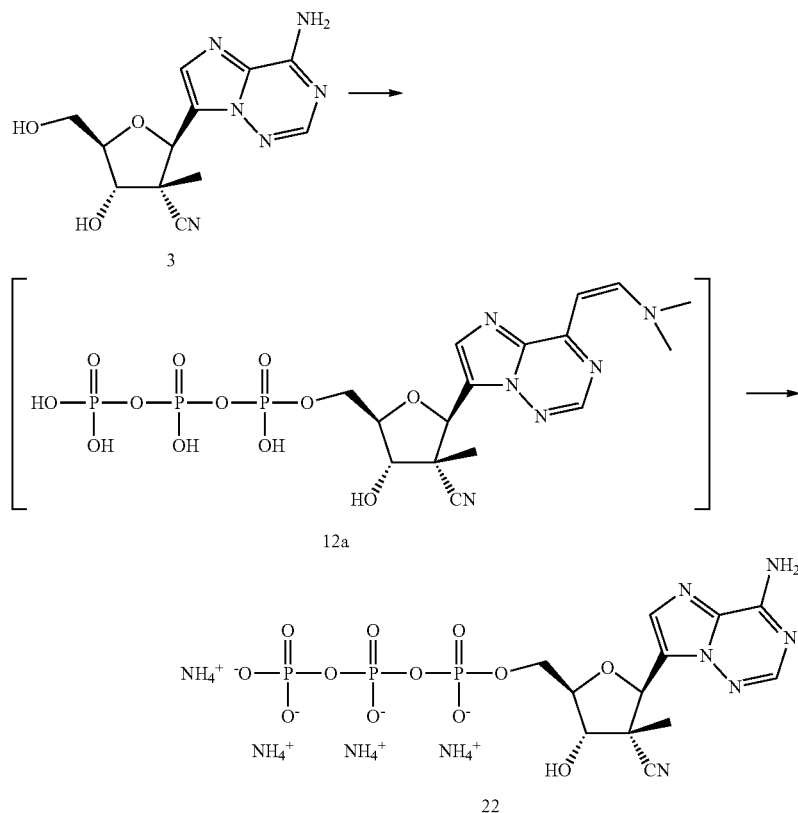
The following compounds of the present invention were made using the methods described in the Example above and substituting the appropriate reactants and/or reagents.

Compd #	Structure	Starting Material	LC-MS or MS(M + H)
18	 <p>Isomer 1</p>	Compound 2	422
19	 <p>Isomer 2</p>	Compound 2	422
20	 <p>Isomer 1</p>	Compound 3	395
21	 <p>Isomer 2</p>	Compound 3	395

83

Example 12

Preparation of Compound 22



84

resulting mixture was concentrated in vacuo and the combined residue was chromatographed on Sephadex DEAE A-25 (HCO_3^-) column, and eluted gradually with 0-2.0 M triethylammonium bicarbonate buffer. The crude product was

Step A—Synthesis of Compound 22

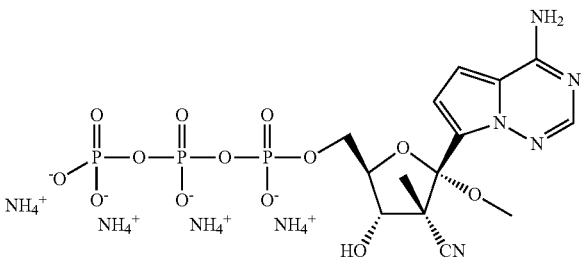
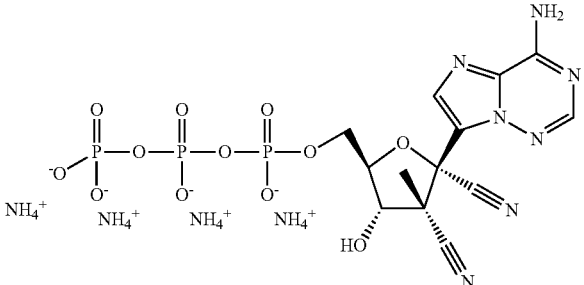
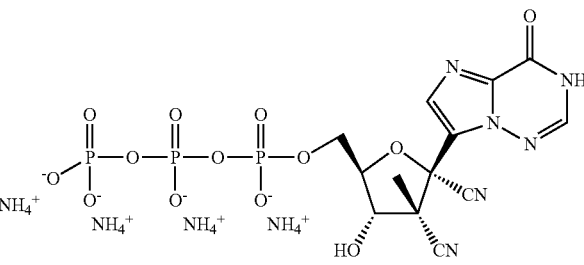
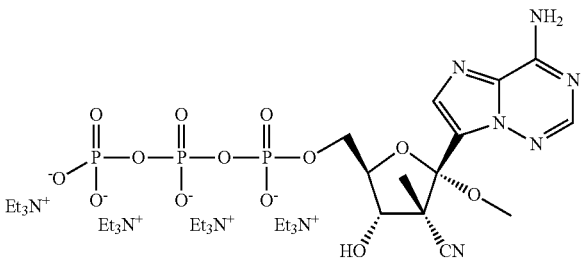
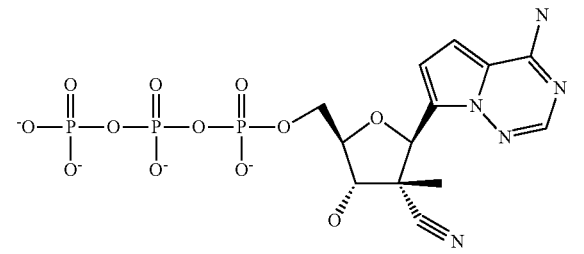
Into a 25-mL round-bottom flask purged and maintained with an inert atmosphere of argon, was placed a solution of compound 3 (25 mg, 0.09 mmol) and proton sponge (28.4 mg, 0.13 mmol) in trimethyl phosphate (1 mL). This was followed by the addition of phosphoryl chloride (0.030 mL, 3.50 equivalents) dropwise with stirring at 0° C. The mixture was stirred for 3 hours at 0° C., and then a solution of pyrophosphate (300 mg, 0.55 mmol) in DMF (1 mL) and tributylamine (0.1 mL) was added. After the resulting solution was stirred for 1 hour at 0° C., it was quenched by the addition of 1M triethylammonium bicarbonate buffer and concentrated in vacuo. The residue was diluted with 2 mL water and 2 mL ammonium hydroxide and stirred overnight at 10-15° C. The

purified by Prep-HPLC with the following conditions (1#-Pre-HPLC-011(Waters)): Column, Atlantis Prep OBD T3 Column, 19*150 mm, Sum; mobile phase, water with 50 mM ammonium bicarbonate and acetonitrile (2% acetonitrile up to 22% in 10 min); Detector, UV 254 & 220 nm. This resulted in 11.7 mg (16%) of compound 22 as a solid. LC-MS: (ES, m/z): 529.00 $[\text{M}-\text{H}]^-$, $^1\text{H-NMR}$: (400 MHz, D_2O , ppm): δ 8.03 (s, 1H), 7.75 (s, 1H), 5.86 (s, 1H), 4.14-4.32 (m, 4H), 1.14 (s, 3H), $^3\text{P-NMR}$: (162 MHz, D_2O , ppm): δ -10.71 (s, 1P), -11.27 (s, 1P), -22.84 (s, 1P)

The following compounds of the present invention were made using the methods described in the Example above and substituting the appropriate reactants and/or reagents.

Compd #	Structure	Starting Material	LC-MS or MS(M + H)
23		Compound 4	549

-continued

Compd #	Structure	Starting Material	LC-MS or MS(M + H)
24		Compound 6	554
25		Compound 5	550
26		Compound 8	551
27		Compound 7	555
1		Compound 2	528

Example 13

Cell-Based HCV Replicon Assay

To measure cell-based anti-HCV activity of selected compounds of the present invention, replicon cells were seeded at 5000 cells/well in 96-well collagen I-coated Nunc plates in

the presence of the test compound. Various concentrations of test compound, typically in 10 serial 2-fold dilutions, were added to the assay mixture, with the starting concentration ranging from 250 μ M to 1 μ M. The final concentration of dimethylsulfoxide was 0.5%, fetal bovine serum was 5%, in the assay media. Cells were harvested on day 3 by the addition of 1 \times cell lysis buffer (Ambion cat #8721). The replicon RNA

87

level was measured using real time PCR (Taqman assay). The amplicon was located in 5B. The PCR primers were: 5B.2F, ATGGACAGGCGCCCTGA (SEQ ID. NO. 1); 5B.2R, TTGATGGGCAGCTTGTTTC (SEQ ID. NO. 2); the probe sequence was FAM-labeled CACGCCATGCGCTGCGG (SEQ ID. NO. 3). GAPDH RNA was used as endogenous control and was amplified in the same reaction as NS5B (multiplex PCR) using primers and VIC-labeled probe recommended by the manufacturer (PE Applied Biosystem). The real-time RT-PCR reactions were run on ABI PRISM 7900HT Sequence Detection System using the following program: 48° C. for 30 minutes, 95° C. for 10 minutes, 40 cycles of 95° C. for 15 sec, 60° C. for 1 minute. The ΔCT values ($CT_{5B} - CT_{GAPDH}$) were plotted against the concentration of test compound and fitted to the sigmoid dose-response model using XLfit4 (MDL). EC_{50} was defined as the concentration of inhibitor necessary to achieve $\Delta CT=1$ over the projected baseline; EC_{90} the concentration necessary to achieve $\Delta CT=3.2$ over the baseline. Alternatively, to quantitate the absolute amount of replicon RNA, a standard curve was established by including serially diluted T7 transcripts of replicon RNA in the Taqman assay. All Taqman reagents were from PE Applied Biosystems. Such an assay procedure was described in detail in e.g. Malcolm et al., *Antimicrobial Agents and Chemotherapy* 50: 1013-1020 (2006).

HCV replicon assay data was calculated for selected compounds of the present invention using this method and the replicon EC_{50} data obtained is provided in the table below.

Compound	1b EC_{50} (μM)
2	>100
3	>100
10	>100
11	35
12	>100
14	>100
15	>100
16	>83
17	34
18	33
19	46

88

-continued

Compound	1b EC_{50} (μM)
20	77
21	>100

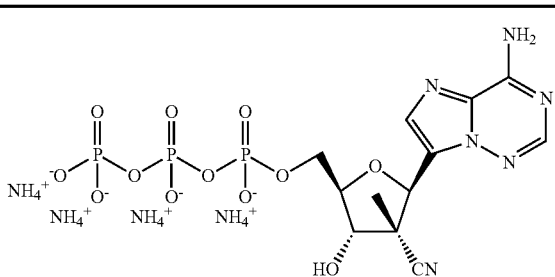
The triphosphate forms or the compounds in the table would be expected to inhibit NS5B polymerase activity. The observed replicon activity can be impacted by different factors including efficiency of initial phosphorylation, the ability to enter the cell and processing of the prodrug.

Example 14

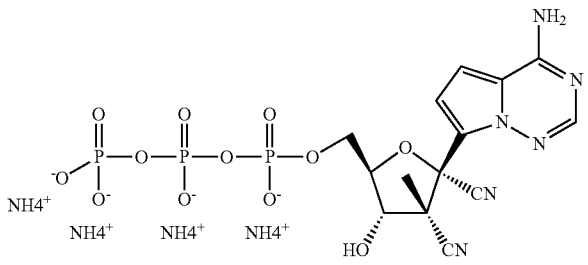
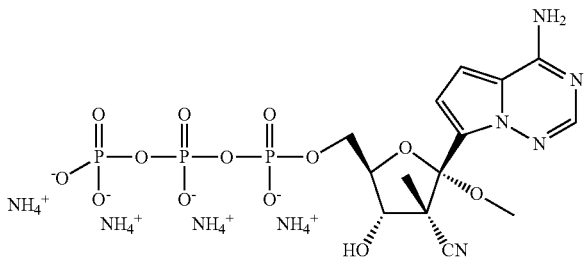
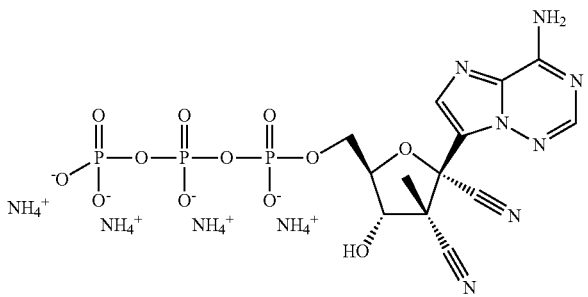
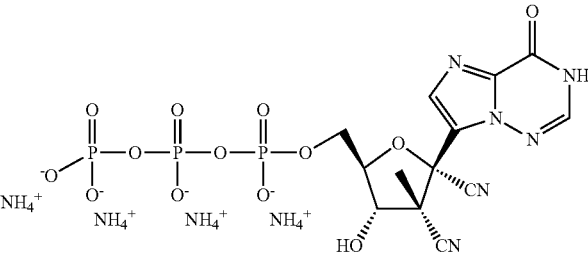
Inhibition of HCV NS5B Polymerase by Nucleoside Triphosphate Analogs

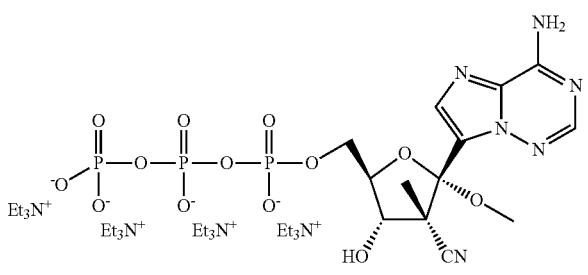
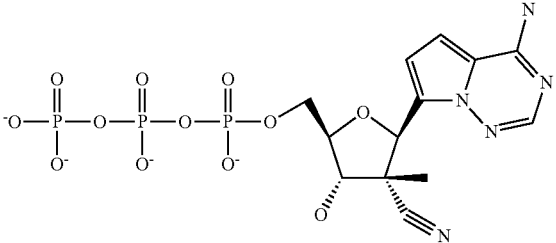
To measure inhibition of the enzymatic activity of the HCV NS5B RNA-dependent RNA polymerase by the nucleoside triphosphate compounds of the present invention, a radiolabeled nucleotide incorporation assay was used. This assay is a modified version of the assay described in International Publication No. WO2002/057287. Briefly, 50 μL reactions containing 20 mM HEPES (pH 7.3); 7.5 mM DTT; 20 units/ml RNasin; 1 μM each of ATP, GTP, UTP and CTP; 20 $\mu Ci/mL$ [^{33}P]-CTP; 10 mM MgCl₂; 60 mM NaCl; 100 $\mu g/mL$ BSA; 0.021 μM DCoH heteropolymer RNA template; and 5 nM NS5B (1b-BK Δ 55) enzyme were incubated at room temperature for 1 hour. The assay was then terminated by the addition of 500 mM EDTA (50 μL). The reaction mixture was transferred to a Millipore DE81 filter plate and the incorporation of labeled CTP is determined using Packard TopCount. Compound IC_{50} values can then be calculated from experiments with 10 serial 3-fold dilutions of the inhibitor in duplicate. The intrinsic potency (K_i) of an NTP inhibitor is derived from its NS5B IC_{50} using the Cheng-Prusoff equation for a competitive inhibitor, as described in Cheng et al., *Biochem Pharmacol* 22:3099-3108 (1973): $K_i = IC_{50} / (1 + [S] / K_m)$, where $[S] = 1 \mu M$, and K_m is the concentration of cognate NTP yielding half-maximal enzyme activity in the assay absent exogenous inhibitors.

Data was obtained using this method for the NTP analogs of selected compounds below of the present invention, and is set forth below.

Compd #	Structure	IC_{50} (μM)
22		0.05

-continued

Compd #	Structure	IC ₅₀ (μ M)
23		1.2
24		0.087
25		87
26		>200

Compd #	Structure	IC ₅₀ (μM)
27		3.8
1		0.003

The present invention is not to be limited by the specific embodiments disclosed in the examples that are intended as illustrations of a few aspects of the invention and any embodiments that are functionally equivalent are within the scope of this invention. Indeed, various modifications of the invention

in addition to those shown and described herein will become apparent to those skilled in the art and are intended to fall within the scope of the appended claims.

A number of references have been cited herein, the entire disclosures of which are incorporated herein by reference.

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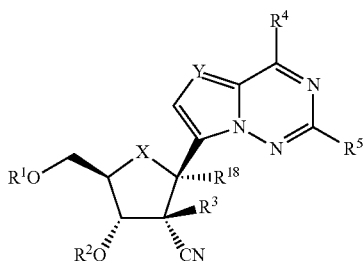
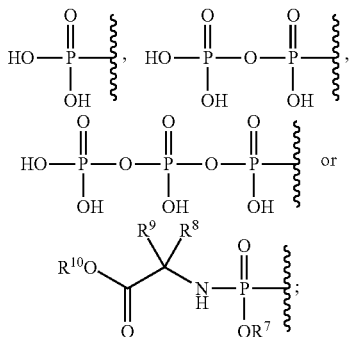
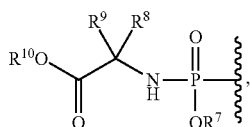
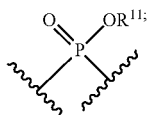
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The invention claimed is:

1. A compound having the structure:

or a pharmaceutically acceptable salt,
wherein:X is O, N, S or CH₂;Y is N or —C(R⁶)—;R¹ is H,R² is H, —C(O)—(C₁-C₆ alkyl) oror R¹ and R² join to form a group having the formula:R³ is C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl or C₃-C₇ cycloalkyl;R⁴ and R⁵ are each independently selected from H, —OR¹², —NHC(O)R¹², —NHC(O)N(R¹²)₂, —N(R¹²)₂ and —NHC(O)R¹²;R⁶ is H, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, halo, —OR¹², —SR¹², —N(R¹²)₂, C₃-C₇ cycloalkyl, C₆-C₁₀ aryl, 5- or 6-membered monocyclic heteroaryl or 9- or 10-membered bicyclic heteroaryl;R⁷ is H, C₆-C₁₀ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, or —(C₁-C₃ alkylene)-C(O)O—(C₁-C₆ alkyl), wherein

94

said C₆-C₁₀ aryl group, said 5- or 6-membered monocyclic heteroaryl group and said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with R¹³,

(I) 5 R⁸ is H, C₁-C₆ alkyl, C₃-C₇ cycloalkyl, phenyl or benzyl, wherein said C₁-C₆ alkyl can be optionally substituted with a group selected from halo, —OR¹², —SR¹², guanidino, —N(R¹²)₂, —C(O)OR¹², —C(O)N(R¹²)₂, —NHC(O)R¹², 5- or 6-membered monocyclic heteroaryl and 9- or 10-membered bicyclic heteroaryl, and wherein said phenyl group and said benzyl group can be optionally substituted with up to 2 groups, each independently selected from C₁-C₆ alkyl, halo and —OR¹²;

10 R⁹ is H, C₁-C₆ alkyl, C₃-C₇ cycloalkyl, phenyl or benzyl, wherein said C₁-C₆ alkyl can be optionally substituted with a group selected from halo, —OR¹², —SR¹², guanidino, —N(R¹²)₂, —C(O)OR¹², —C(O)N(R¹²)₂, —NHC(O)R¹², 5- or 6-membered monocyclic heteroaryl and 9- or 10-membered bicyclic heteroaryl, and wherein said phenyl group and said benzyl group can be optionally substituted with up to 2 groups, each independently selected from C₁-C₆ alkyl, halo and —OR¹²;

15 R¹⁰ is H, C₁-C₂₀ alkyl, C₂-C₂₀ alkenyl, —(C₁-C₃ alkylene)_m-(C₃-C₇ cycloalkyl), —(C₁-C₃ alkylene)_m-(C₆-C₁₀ aryl) or —(C₁-C₃ alkylene)_m-adamantyl, wherein said C₁-C₂₀ alkyl group, said C₂-C₂₀ alkenyl group, said C₆-C₁₀ aryl group and said adamantyl group can be optionally substituted with up to three groups, each independently selected from halo, —OR¹², —C(O)OR¹², CN, NO₂, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, C₃-C₇ cycloalkyl, C₆-C₁₀ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, —N(R¹²)₂, —C(O)N(R¹²)₂, —SR¹², —S(O)R¹², —S(O)₂R¹², —S(O)₂N(R¹²)₂, —NHC(O)R¹², —NHC(O)OR¹² and —NHC(O)N(R¹²)₂;

20 R¹¹ is H, C₁-C₂₀ alkyl, C₂-C₂₀ alkenyl, —(C₁-C₃ alkylene)_m-(C₃-C₇ cycloalkyl), C₃-C₇ cycloalkyl, —(C₁-C₃ alkylene)_m-C₆-C₁₀ aryl or —(C₁-C₃ alkylene)_m-adamantyl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, wherein said C₁-C₂₀ alkyl group, said C₂-C₂₀ alkenyl group, said C₆-C₁₀ aryl group, said adamantyl group, said 5- or 6-membered monocyclic heteroaryl group and said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with up to five groups, each independently selected from C₁-C₆ alkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, C₃-C₇ cycloalkyl, C₆-C₁₀ aryl, 5- or 6-membered monocyclic heteroaryl, 9- or 10-membered bicyclic heteroaryl, halo, —OR¹², —SR¹², —S(O)R¹², —S(O)₂R¹², —S(O)₂N(R¹²)₂, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, —O—(C₁-C₆ haloalkyl), —CN, —NO₂, —N(R¹²)₂, —C(O)OR¹², —C(O)N(R¹²)₂ and —NHC(O)R¹², —NHC(O)OR¹² and —NHC(O)N(R¹²)₂;

25 each occurrence of R¹² is independently H, C₁-C₁₀ alkyl, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, —(C₁-C₃ alkylene)_m-(C₃-C₇ cycloalkyl), —(C₁-C₃ alkylene)_m-(C₆-C₁₀ aryl), —(C₁-C₃ alkylene)_m-(4 to 7-membered heterocycloalkyl), —(C₁-C₃ alkylene)_m-(5- or 6-membered monocyclic heteroaryl) or —(C₁-C₃ alkylene)_m-(9- or 10-membered bicyclic heteroaryl), wherein said C₃-C₇ cycloalkyl group, said C₆-C₁₀ aryl group, said 4 to 7-membered heterocycloalkyl group, said 5- or 6-membered monocyclic heteroaryl group or said 9- or 10-membered bicyclic heteroaryl group can be optionally substituted with R¹⁶;

30 R¹³ represents from one to five substituent groups, each independently selected from C₁-C₆ alkyl, halo, —OR¹²,

95

—SR¹², C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, —O—(C₁-C₆ haloalkyl), —CN, —NO₂, —N(R¹²)₂, —C(O)OR¹², —C(O)N(R¹²)₂ and —NHC(O)R¹², or any two R¹³ groups on adjacent ring carbon atoms can combine to form —O—R¹⁴—O—;

R¹⁴ is —[C(R¹⁵)₂]_n—;

each occurrence of R¹⁵ is independently H or C₁-C₆ alkyl;

R¹⁶ represents from one to five substituent groups, each independently selected from C₁-C₆ alkyl, C₂-C₆ alkenyl, C₂-C₆ alkynyl, halo, —OR¹⁷, —SR¹⁷, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, —O—(C₁-C₆ haloalkyl), —CN, —NO₂, —N(R¹⁷)₂, —C(O)OR¹⁷, —C(O)N(R¹⁷)₂ and —NHC(O)R¹⁷;

each occurrence of R¹⁷ is independently H, C₁-C₆ alkyl, C₁-C₆ haloalkyl, C₁-C₆ hydroxyalkyl, —(C₁-C₃ alkylene)_m-(C₃-C₇ cycloalkyl), —(C₁-C₃ alkylene)_m-(C₆-C₁₀ aryl), —(C₁-C₃ alkylene)_m-(4 to 7-membered heterocycloalkyl), —(C₁-C₃ alkylene)_m-(5- or 6-membered monocyclic heteroaryl) or —(C₁-C₃ alkylene)_m-(9- or 10-membered bicyclic heteroaryl);

R¹⁸ is H, C₁-C₆ alkyl, —O(C₁-C₆ alkyl), C₁-C₆ alkynyl, C₁-C₆ alkenyl, or CN; and

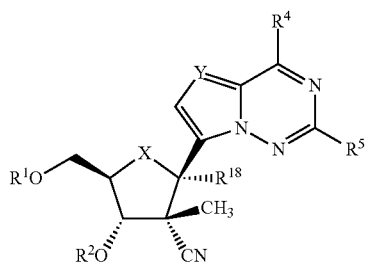
each occurrence of m is independently 0 or 1, and

each occurrence of n is independently 1, 2, or 3.

2. The compound of claim 1, wherein X is O.

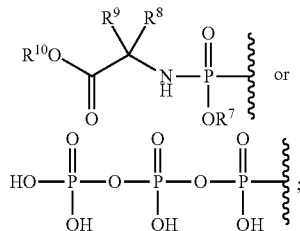
3. The compound of claim 2, wherein R³ is methyl.

4. The compound of claim 1 having the formula:

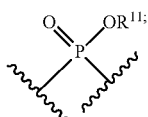


or a pharmaceutically acceptable salt thereof, wherein:

R¹ is H,



R² is H, or R¹ and R² join to form a group having the formula:



R⁴ is H, OH or —N(R¹²)₂;

96

R⁵ is H or NH₂,

R¹⁸ is H, —CN or —OCH₃;

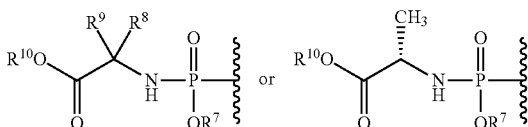
R⁷ is —(C₁-C₃ alkylene)-C(O)O—(C₁-C₆ alkyl) or phenyl, wherein said phenyl group can be optionally substituted with a halo group;

R⁸ and R⁹ are each independently H or C₁-C₆ alkyl;

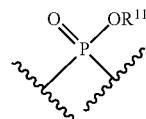
R¹⁰ is C₁-C₆ alkyl; and

R¹¹ is C₆ alkyl or C₃-C₇ cycloalkyl.

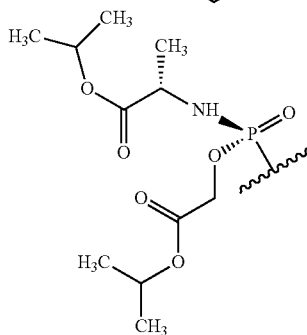
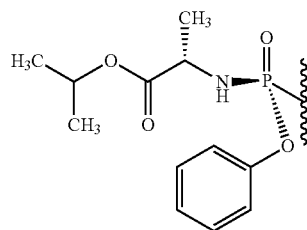
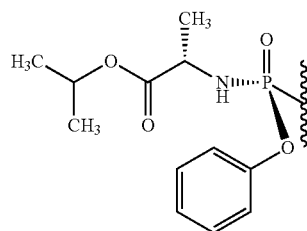
5. The compound of claim 4, wherein R¹ is:



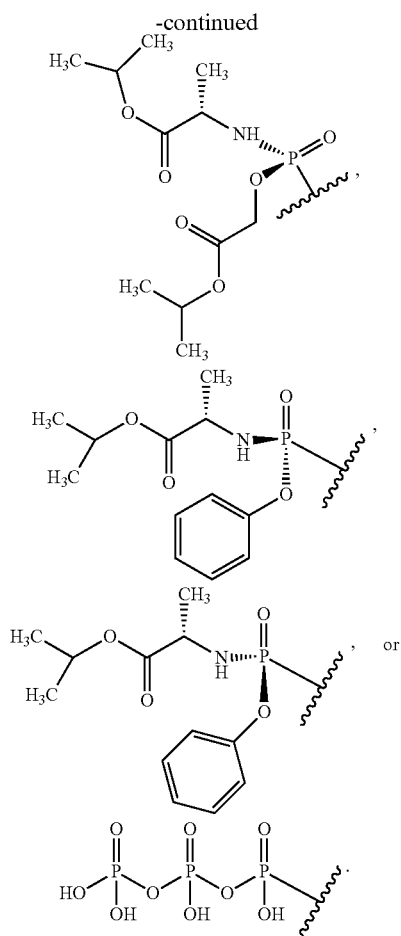
6. The compound of claim 4, wherein R¹ and R² join to form a group having the formula:



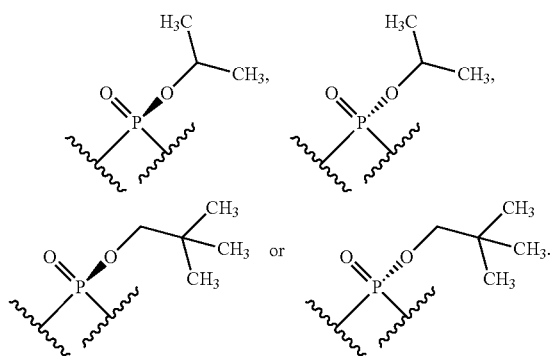
7. The compound of claim 5, wherein R¹ is:



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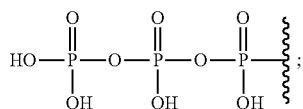


8. The compound of claim 6, wherein R^1 and R^2 join to form a group having the structure:



9. The compound of claim 4, wherein Y is N or CH, R^4 is NH_2 and R^5 is H.

10. The compound of claim 4, wherein R^1 is H or



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R^2 is H; and

R^4 is NH_2 or OH.

11. The compound of claim 1 having the structure:

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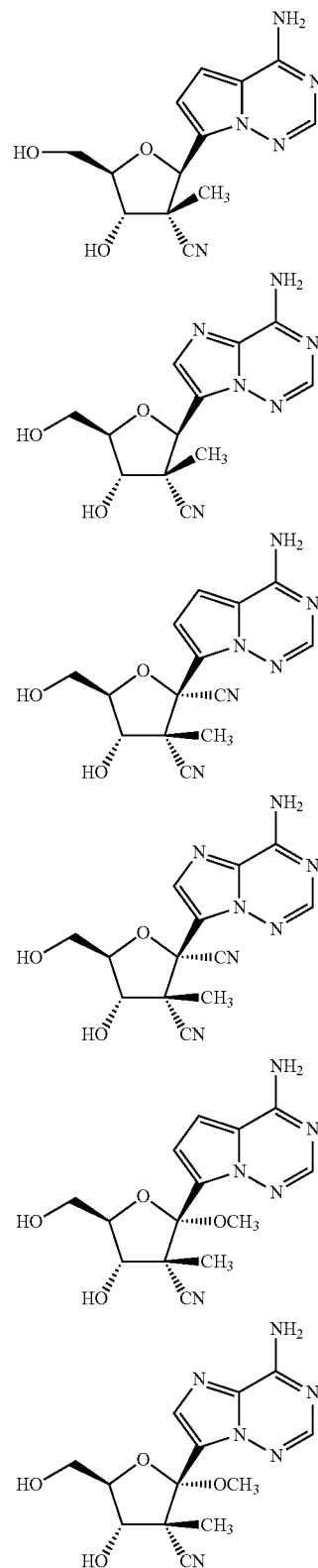
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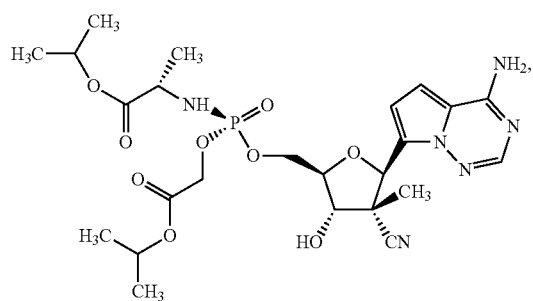
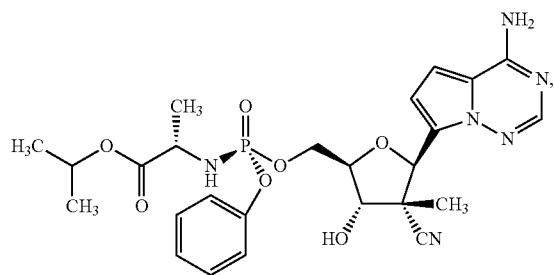
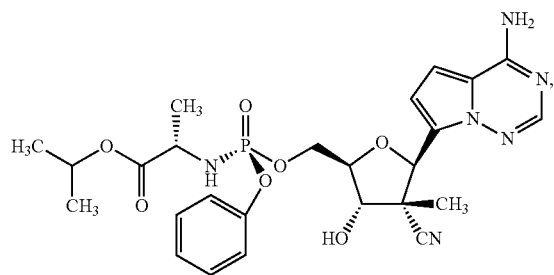
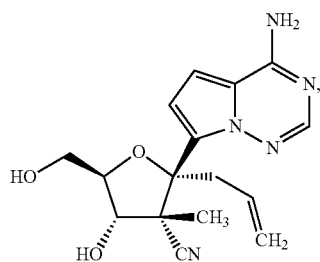
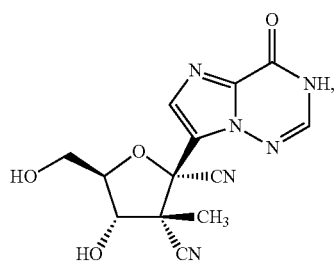
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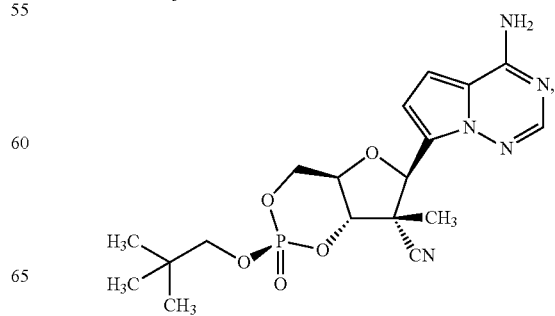
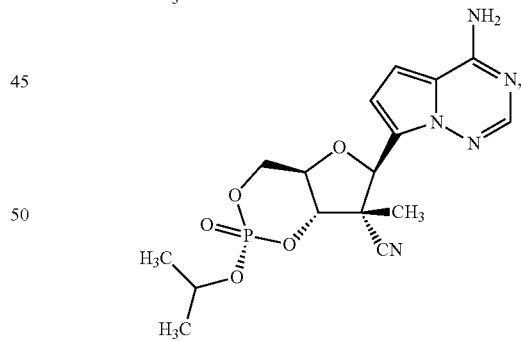
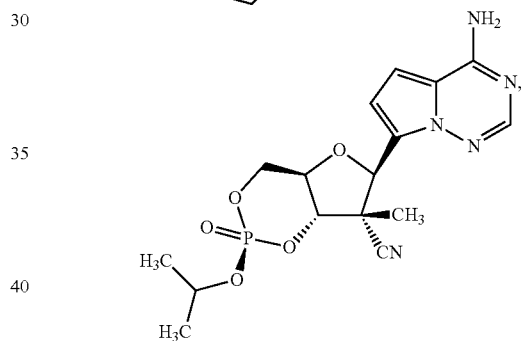
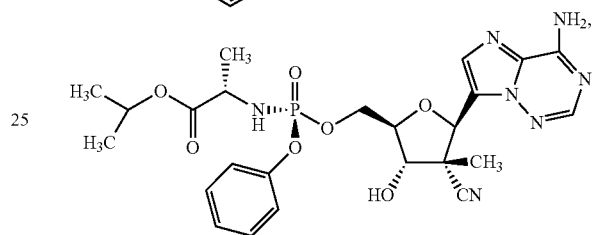
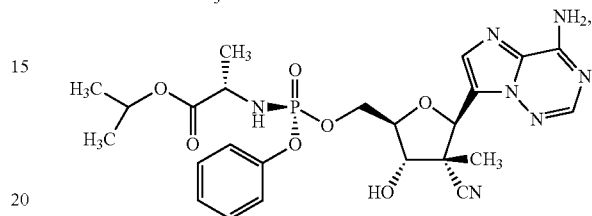
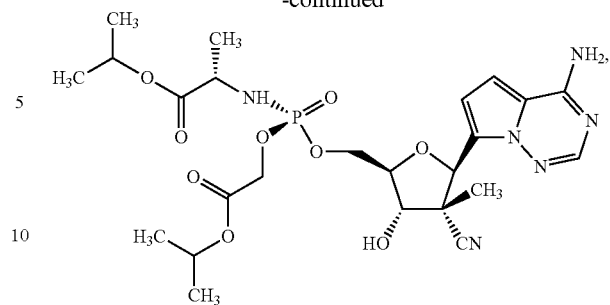


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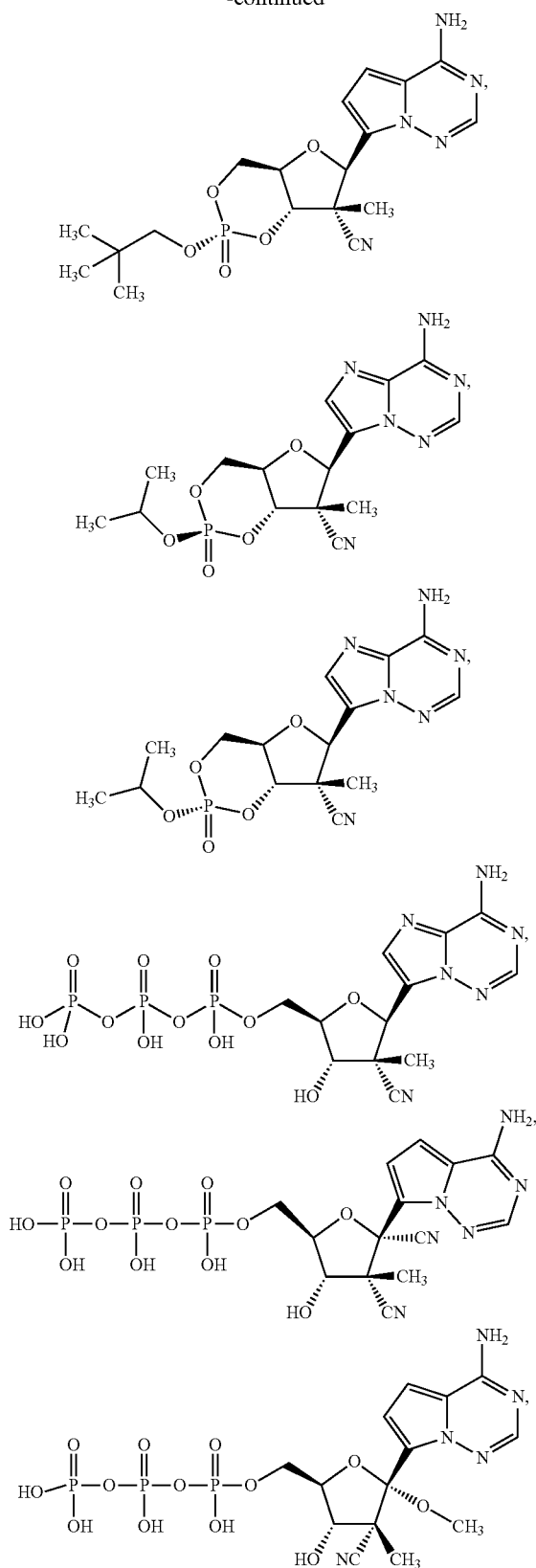
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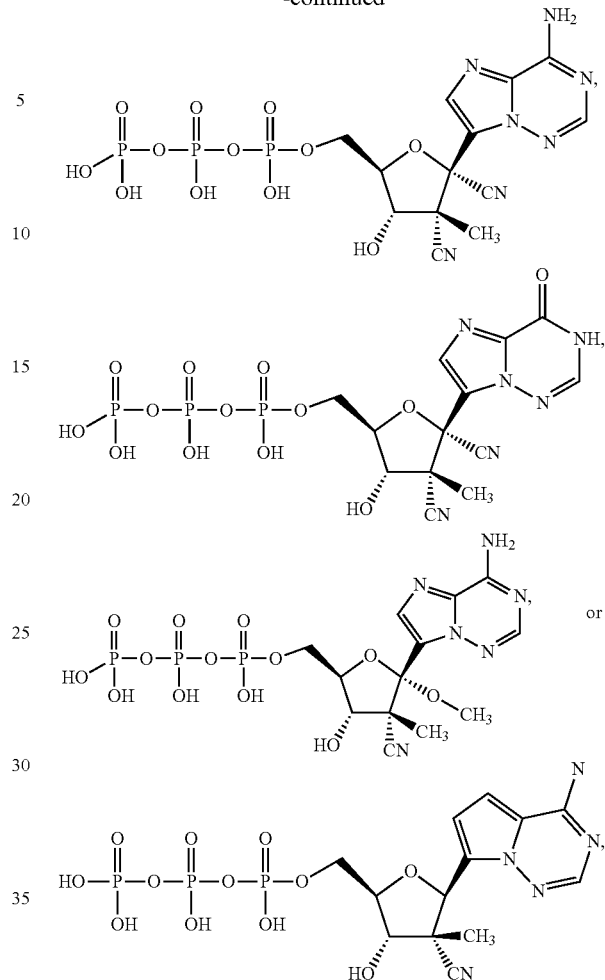


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40 or a pharmaceutically acceptable salt thereof.

12. A pharmaceutical composition comprising an effective amount of the compound of claim 1 or a pharmaceutically acceptable salt thereof, and a pharmaceutically acceptable carrier.

13. The pharmaceutical composition according to claim 12, further comprising a second therapeutic agent selected from the group consisting of HCV antiviral agents, immuno-modulators, and anti-infective agents.

14. The pharmaceutical composition according to claim 13, further comprising a third therapeutic agent selected from the group consisting of HCV protease inhibitors, HCV NS5A inhibitors and HCV NS5B polymerase inhibitors.

15. A method of treating a patient infected with HCV comprising the step of administering an amount of (i) the compound according to claim 1, or a pharmaceutically acceptable salt thereof, or (ii) a pharmaceutical composition comprising said compound and a pharmaceutically acceptable carrier effective to treat infection by HCV in said patient.

16. The method according to claim 15, further comprising the step of administering pegylated-interferon alpha and an HCV protease inhibitor to said patient.

17. The method according to claim 15 further comprising the step of administering ribavirin to said patient.

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